US006341277B1

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Coden et al.

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(45) Date of Patent: **Jan. 22, 2002**

(54) **SYSTEM AND METHOD FOR PERFORMANCE COMPLEX HETEROGENEOUS DATABASE QUERIES USING A SINGLE SQL EXPRESSION**

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(73) Assignee: **International Business Machines Corporation**, Armonk, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/289,020**

(22) Filed: **Apr. 9, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/108,754, filed on Nov. 17, 1998.

(51) **Int. Cl.**[7] **G06F 17/30**

(52) **U.S. Cl.** **707/2; 707/3; 707/4; 707/5; 707/100**

(58) **Field of Search** 707/2–5, 100

(56) **References Cited**

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6,167,393 A * 12/2000 Davis, III et al. 707/3

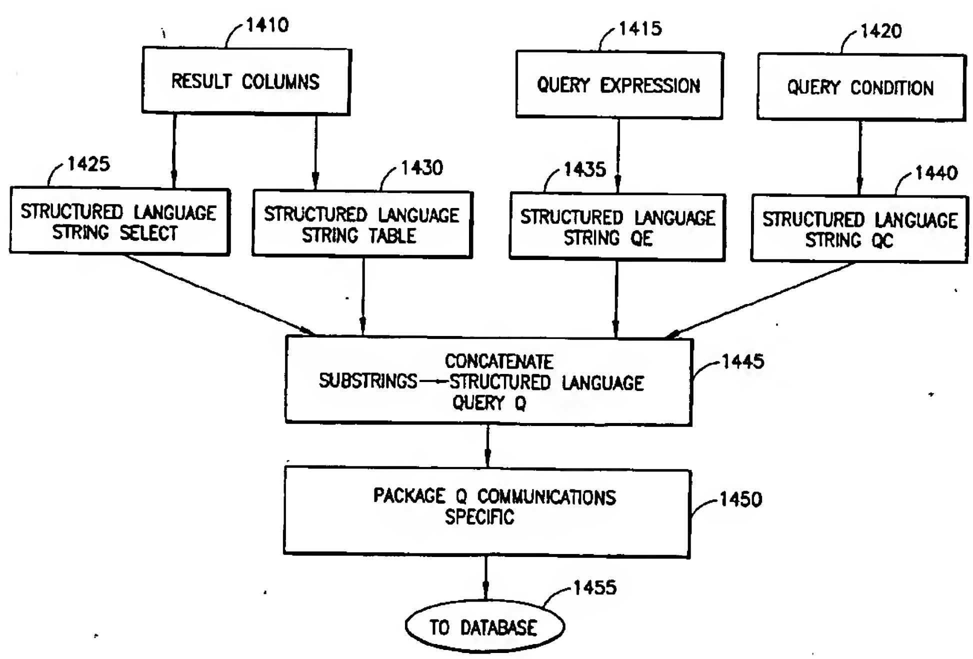
* cited by examiner

Primary Examiner—Hosain T. Alam
Assistant Examiner—Cam-Y Truong
(74) *Attorney, Agent, or Firm*—Louis J. Percello

(57) **ABSTRACT**

Query objects are created by a client process. The query objects have one or more sub-query objects and one or more execute methods that are capable of operating on their respective query object to produce one or more query expressions. All of the execute methods are capable of producing the respective query expression that is compatible with a structured query language. A compound query contains one or more boolean expressions of one or more of the query objects. The compound query has one or more compound execute methods which invoke one or more the execute methods of each of the query objects. Each of the execute methods returns their respective query expression and the compound execute method uses one or more common table expressions to combine the query expressions to form a single compound query expression that represents the boolean expression. This single expression can be execute against a database to return a result without executing any of the query expressions against the database individually.

18 Claims, 33 Drawing Sheets



06/04/2004, EAST Version: 1.4.1

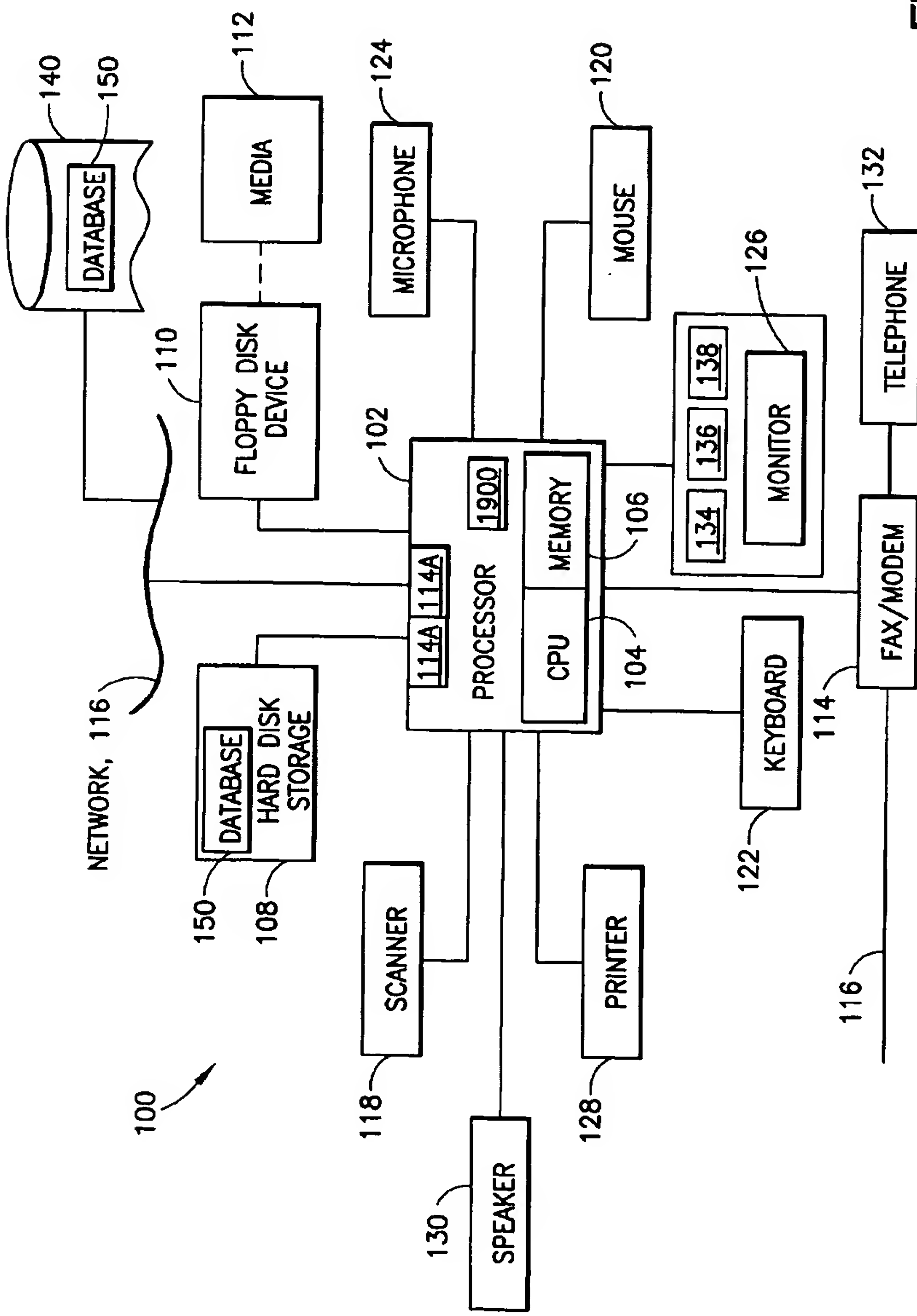

140
150
DATABASE
112
MEDIA
124
MICROPHONE
120
MOUSE
110
FLOPPY DISK DEVICE
102
1900
MEMORY
106
PROCESSOR
114A
114A
CPU
104
126
134
136
138
MONITOR
132
TELEPHONE
FAX/MODEM
114
KEYBOARD
122
NETWORK, 116
DATABASE
HARD DISK STORAGE
150
108
SCANNER
118
PRINTER
128
SPEAKER
130
100
116

FIG.1

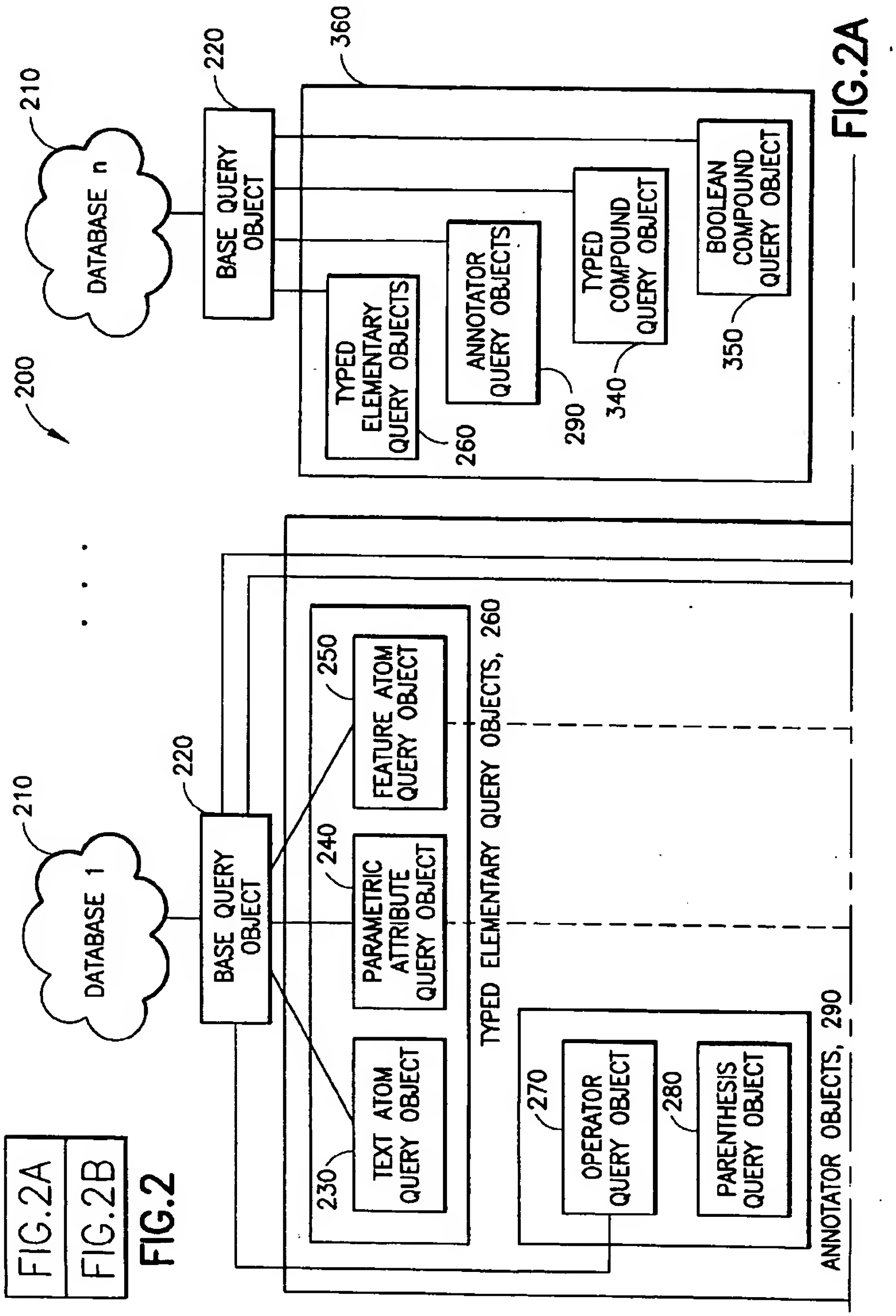

200
210
DATABASE n
220
BASE QUERY OBJECT
360
TYPED ELEMENTARY QUERY OBJECTS
260
ANNOTATOR QUERY OBJECTS
290
TYPED COMPOUND QUERY OBJECT
340
BOOLEAN COMPOUND QUERY OBJECT
350
210
DATABASE 1
220
BASE QUERY OBJECT
230
TEXT ATOM QUERY OBJECT
240
PARAMETRIC ATTRIBUTE QUERY OBJECT
250
FEATURE ATOM QUERY OBJECT
TYPED ELEMENTARY QUERY OBJECTS, 260
270
OPERATOR QUERY OBJECT
280
PARENTHESIS QUERY OBJECT
ANNOTATOR OBJECTS, 290
FIG.2A
FIG.2B

FIG.2

FIG.2A

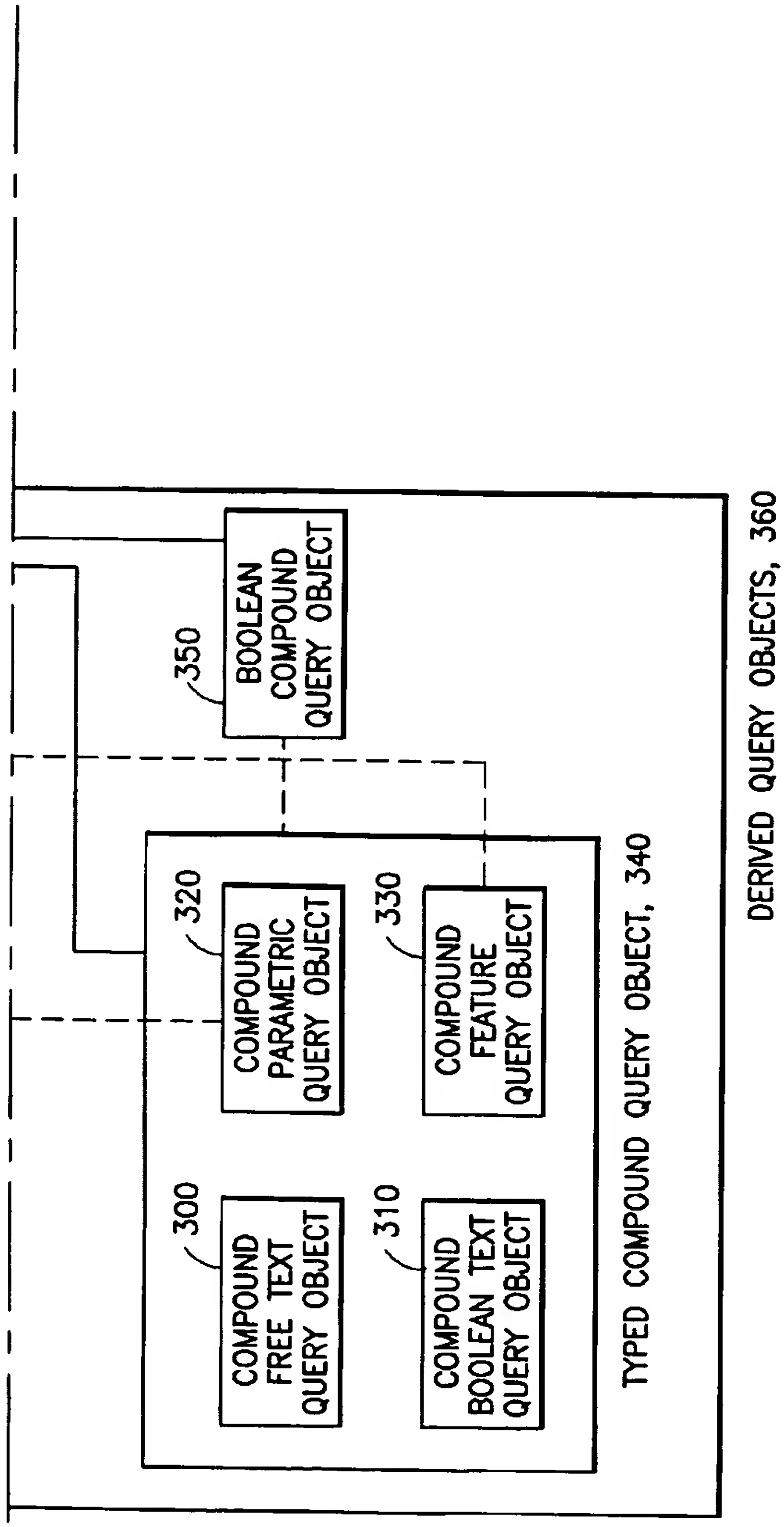

350
BOOLEAN COMPOUND QUERY OBJECT
300
COMPOUND FREE TEXT QUERY OBJECT
320
COMPOUND PARAMETRIC QUERY OBJECT
310
COMPOUND BOOLEAN TEXT QUERY OBJECT
330
COMPOUND FEATURE QUERY OBJECT
TYPED COMPOUND QUERY OBJECT, 340
DERIVED QUERY OBJECTS, 360

FIG.2B

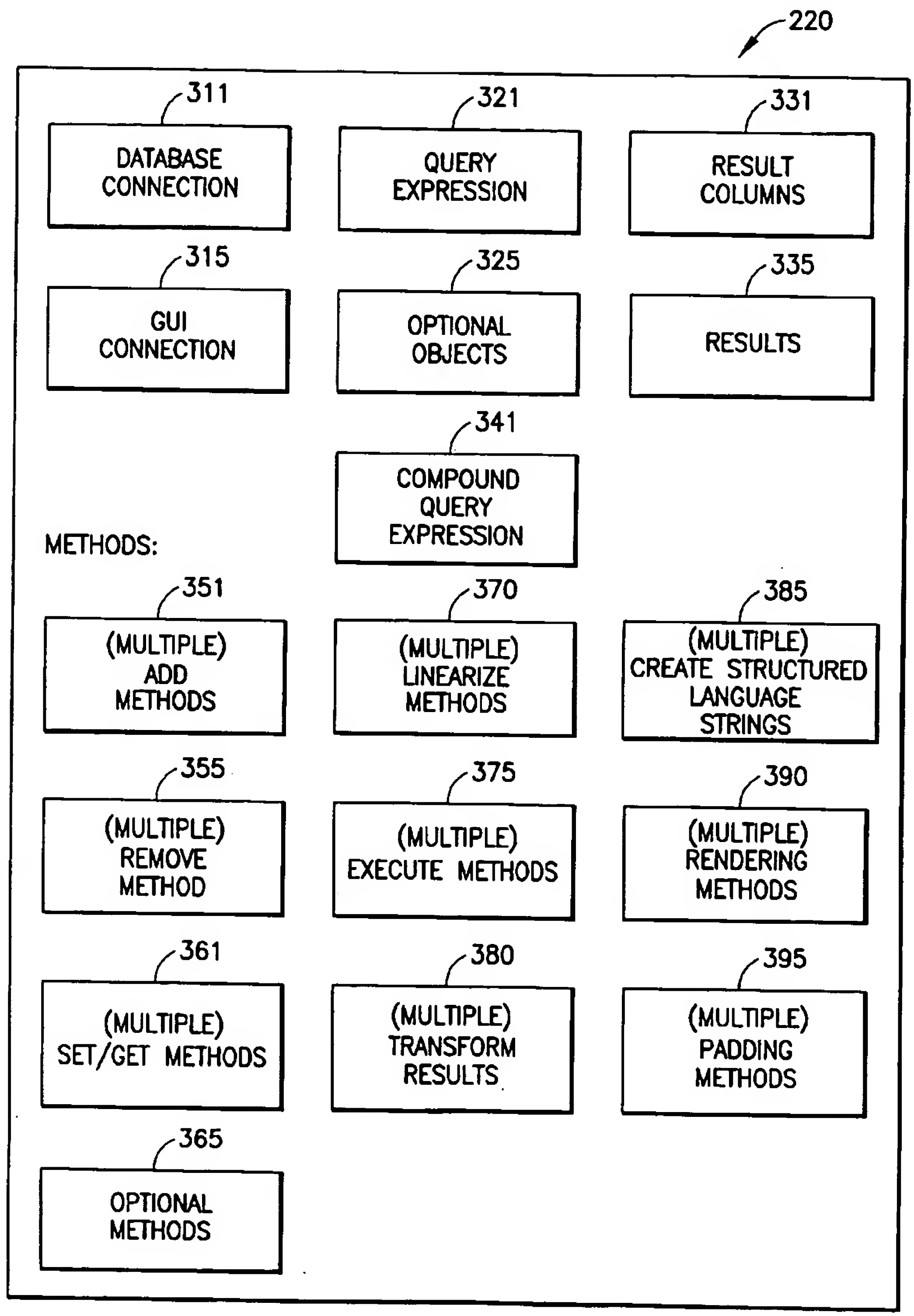

220
311
DATABASE CONNECTION
321
QUERY EXPRESSION
331
RESULT COLUMNS
315
GUI CONNECTION
325
OPTIONAL OBJECTS
335
RESULTS
341
COMPOUND QUERY EXPRESSION
METHODS:
351
(MULTIPLE) ADD METHODS
370
(MULTIPLE) LINEARIZE METHODS
385
(MULTIPLE) CREATE STRUCTURED LANGUAGE STRINGS
355
(MULTIPLE) REMOVE METHOD
375
(MULTIPLE) EXECUTE METHODS
390
(MULTIPLE) RENDERING METHODS
361
(MULTIPLE) SET/GET METHODS
380
(MULTIPLE) TRANSFORM RESULTS
395
(MULTIPLE) PADDING METHODS
365
OPTIONAL METHODS

FIG.3

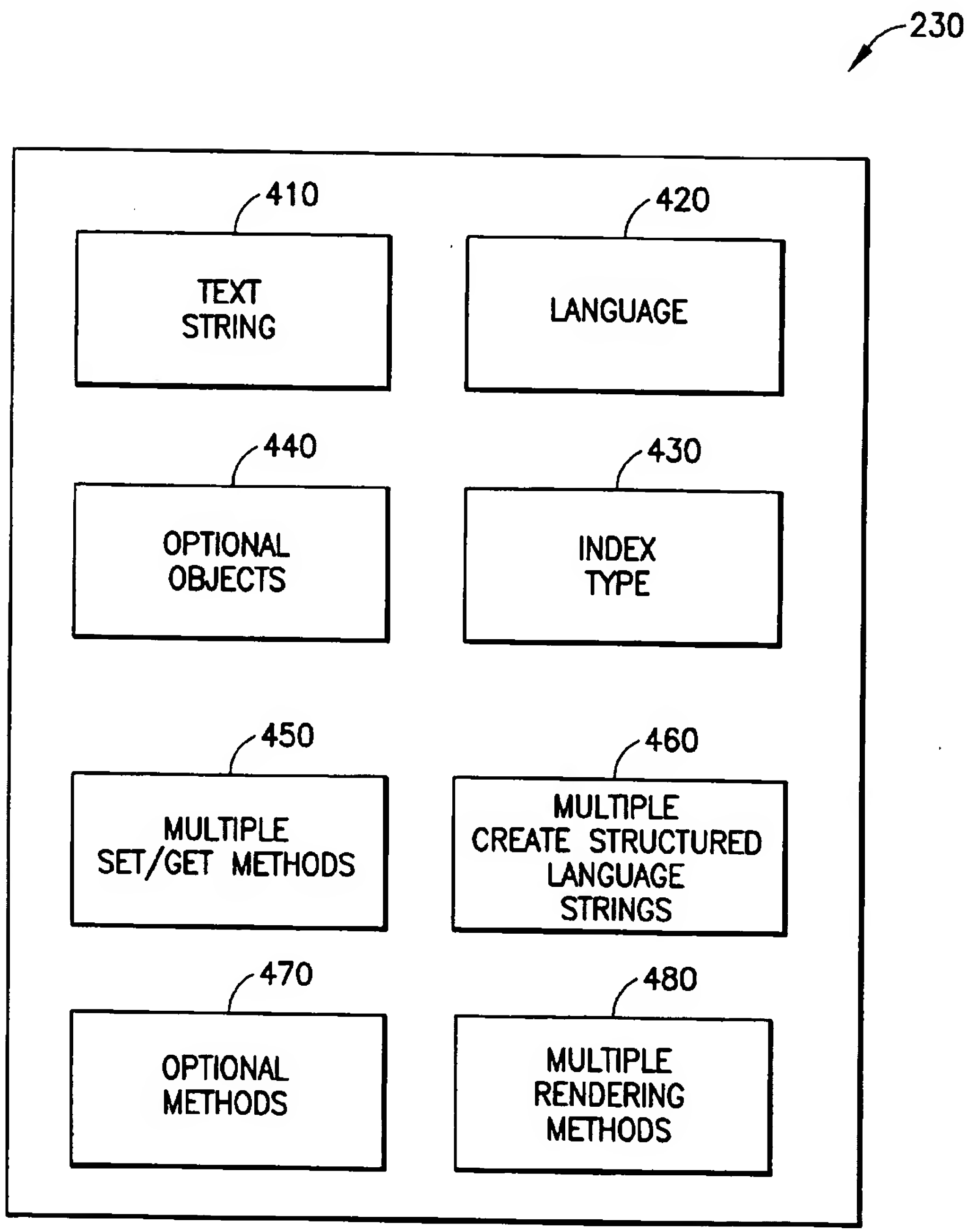

230
410
TEXT STRING
420
LANGUAGE
440
OPTIONAL OBJECTS
430
INDEX TYPE
450
MULTIPLE SET/GET METHODS
460
MULTIPLE CREATE STRUCTURED LANGUAGE STRINGS
470
OPTIONAL METHODS
480
MULTIPLE RENDERING METHODS

FIG.4

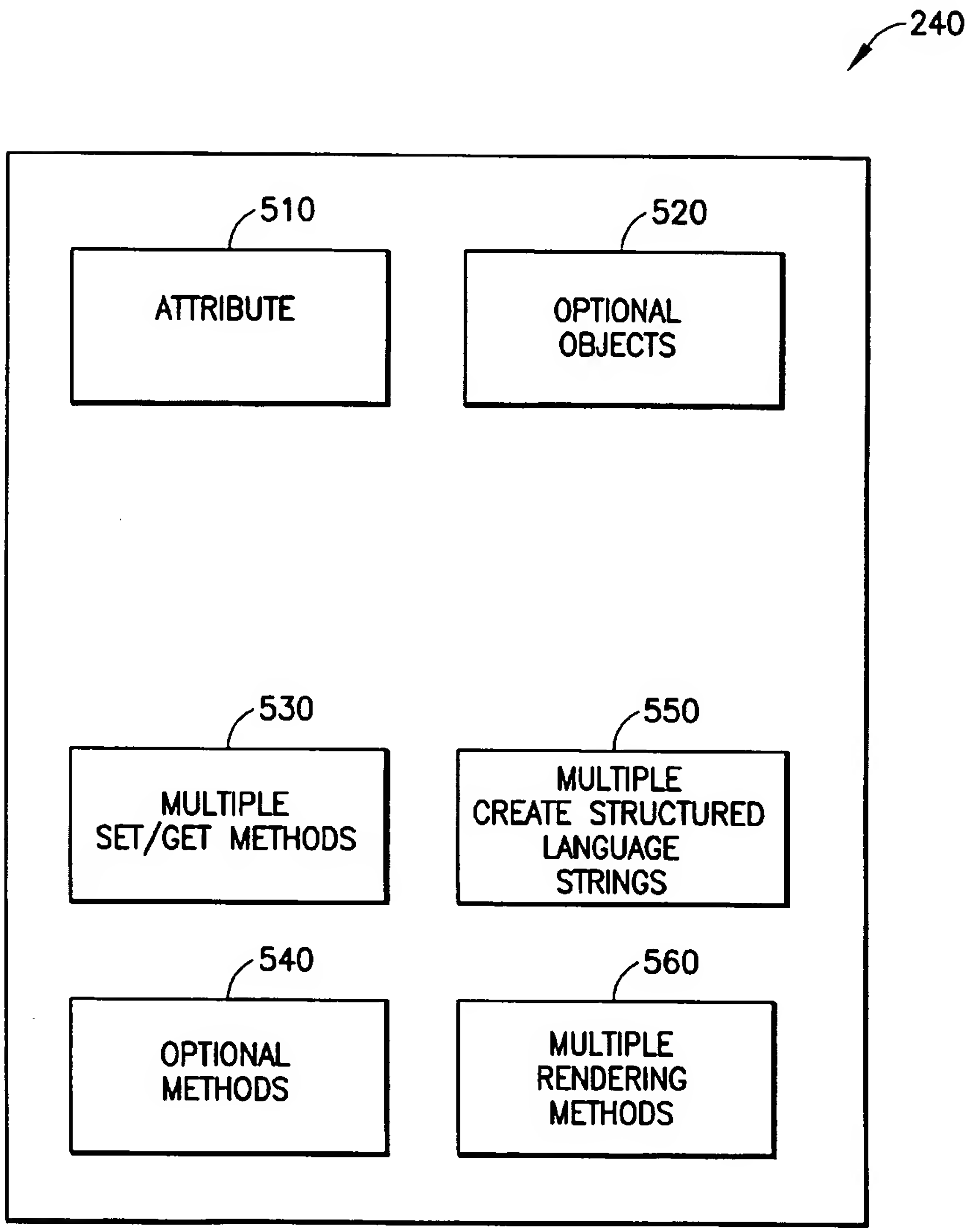

240
510
ATTRIBUTE
520
OPTIONAL OBJECTS
530
MULTIPLE SET/GET METHODS
550
MULTIPLE CREATE STRUCTURED LANGUAGE STRINGS
540
OPTIONAL METHODS
560
MULTIPLE RENDERING METHODS

FIG.5

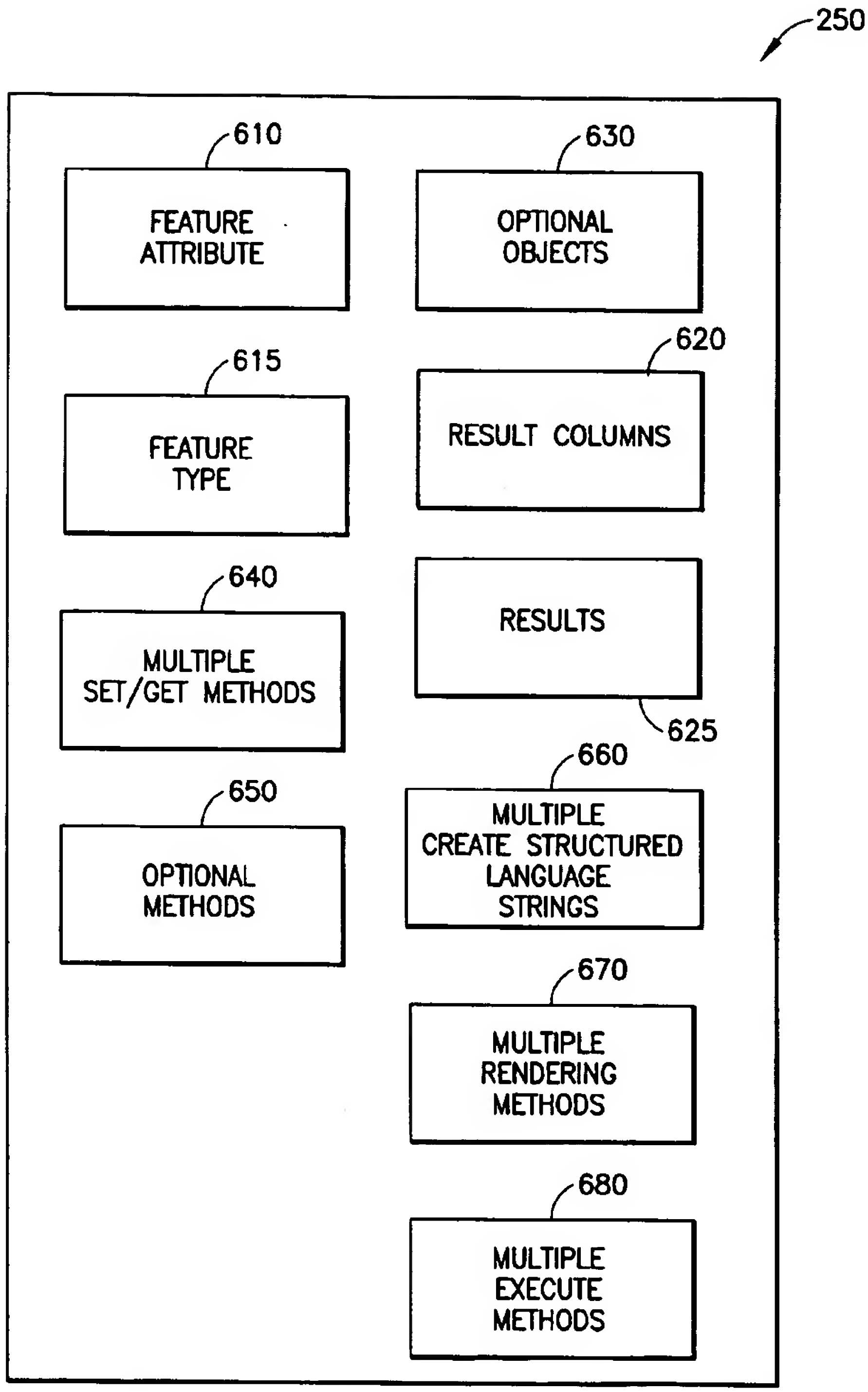

250
610
FEATURE ATTRIBUTE
630
OPTIONAL OBJECTS
615
FEATURE TYPE
620
RESULT COLUMNS
640
MULTIPLE SET/GET METHODS
RESULTS
625
660
MULTIPLE CREATE STRUCTURED LANGUAGE STRINGS
650
OPTIONAL METHODS
670
MULTIPLE RENDERING METHODS
680
MULTIPLE EXECUTE METHODS

FIG.6

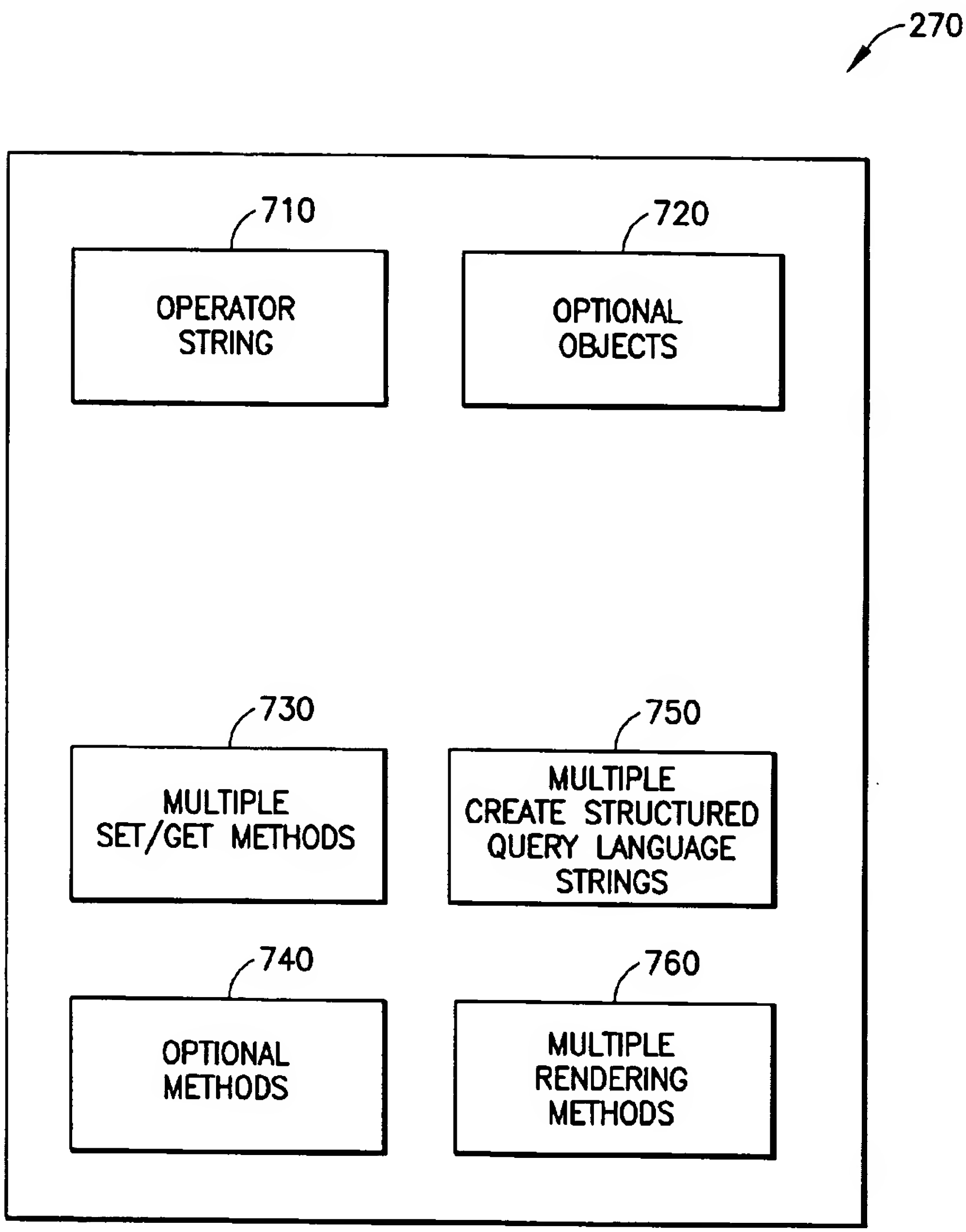

270
710
OPERATOR STRING
720
OPTIONAL OBJECTS
730
MULTIPLE SET/GET METHODS
750
MULTIPLE CREATE STRUCTURED QUERY LANGUAGE STRINGS
740
OPTIONAL METHODS
760
MULTIPLE RENDERING METHODS

FIG.7

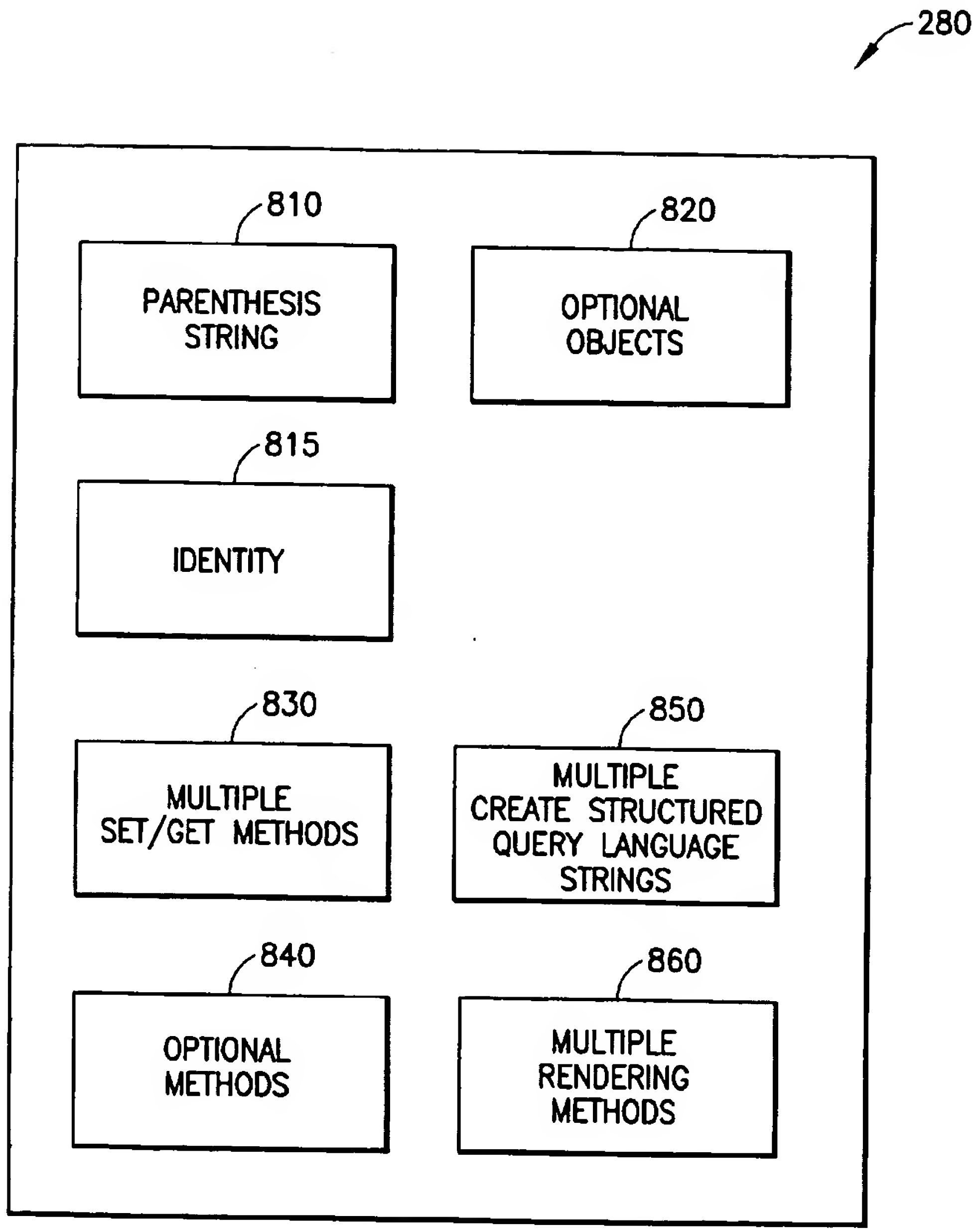

280
810
PARENTHESIS STRING
820
OPTIONAL OBJECTS
815
IDENTITY
830
MULTIPLE SET/GET METHODS
850
MULTIPLE CREATE STRUCTURED QUERY LANGUAGE STRINGS
840
OPTIONAL METHODS
860
MULTIPLE RENDERING METHODS

FIG.8

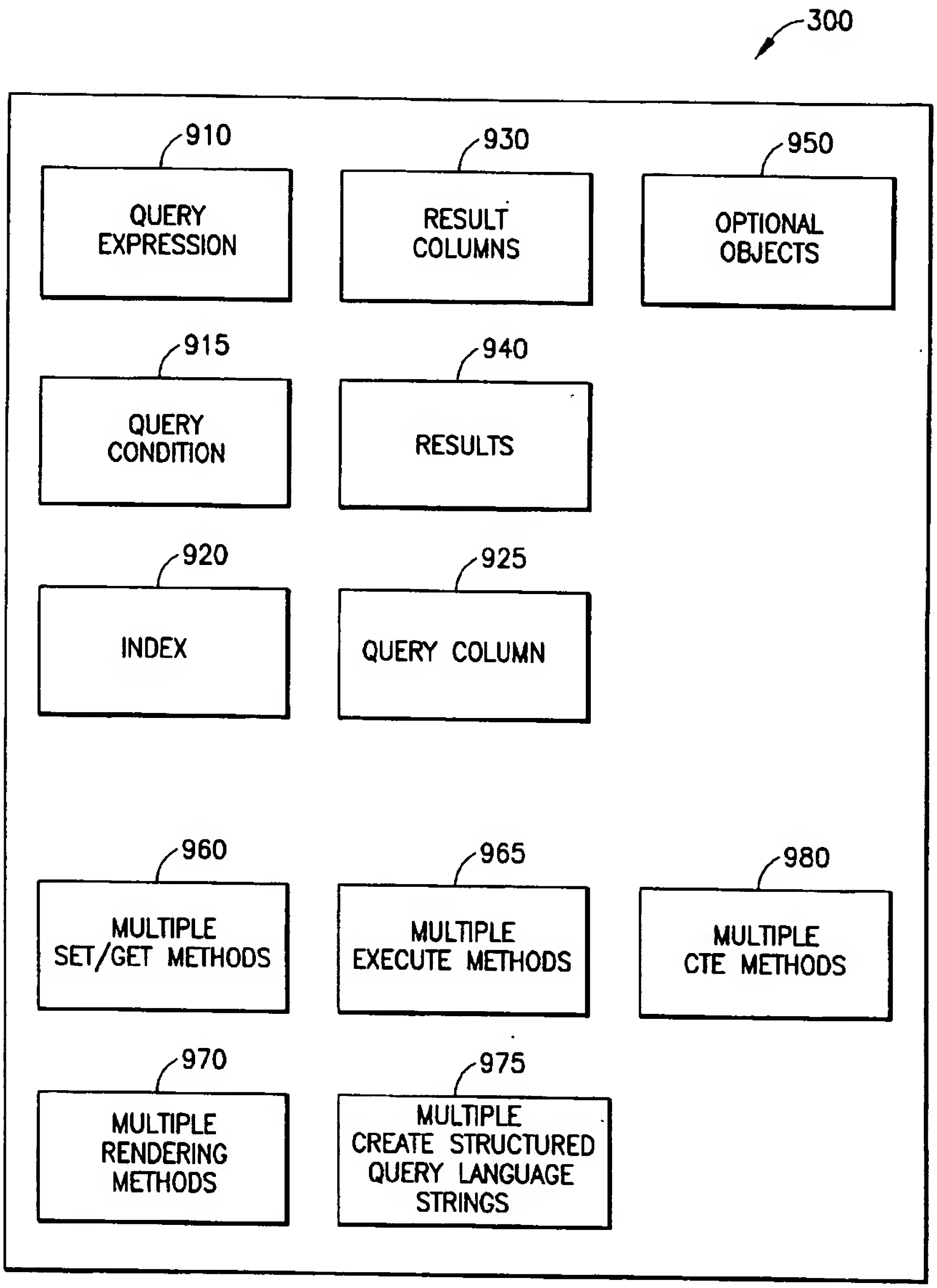

300
910
QUERY EXPRESSION
930
RESULT COLUMNS
950
OPTIONAL OBJECTS
915
QUERY CONDITION
940
RESULTS
920
INDEX
925
QUERY COLUMN
960
MULTIPLE SET/GET METHODS
965
MULTIPLE EXECUTE METHODS
980
MULTIPLE CTE METHODS
970
MULTIPLE RENDERING METHODS
975
MULTIPLE CREATE STRUCTURED QUERY LANGUAGE STRINGS

FIG.9

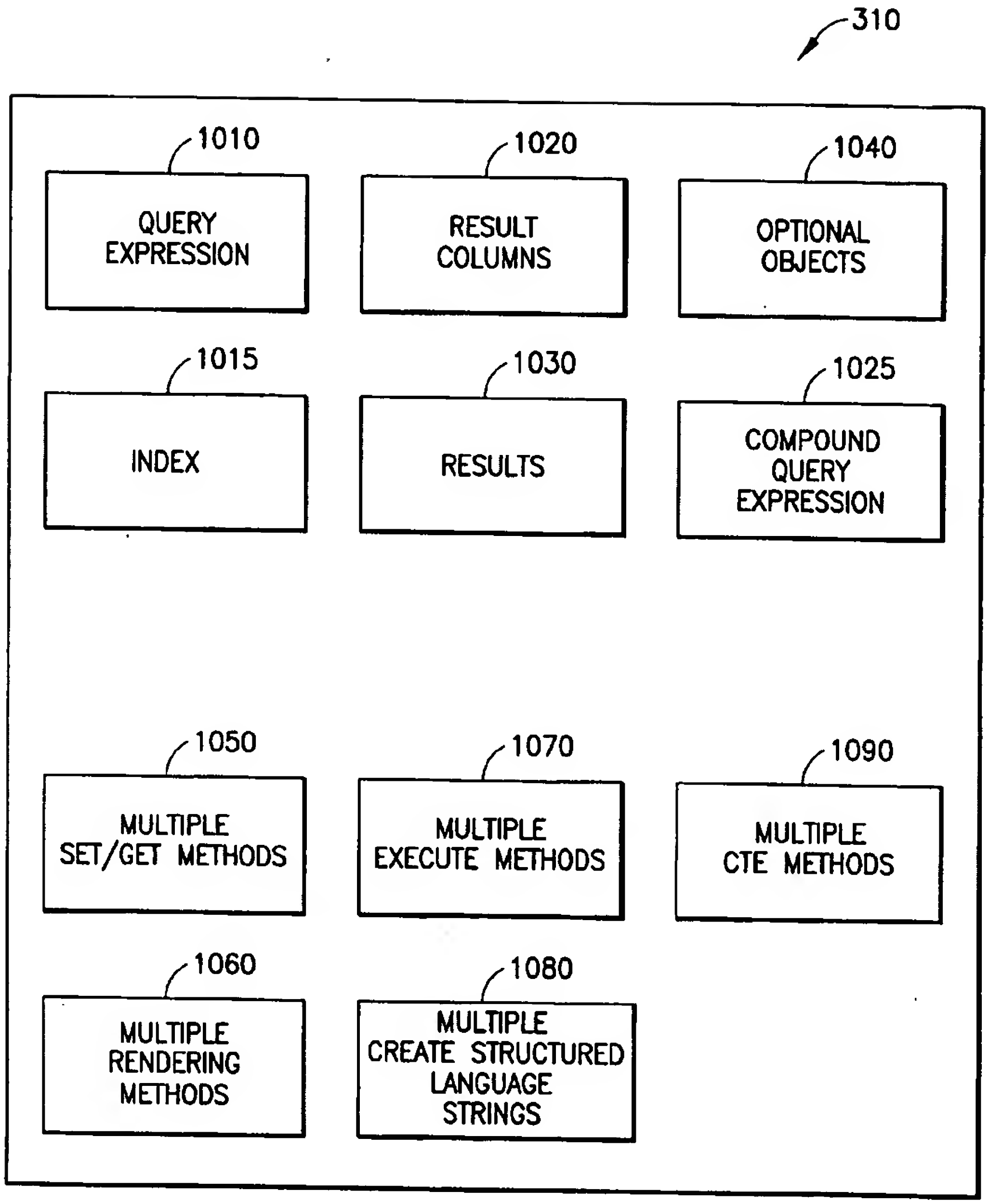

310
1010
QUERY EXPRESSION
1020
RESULT COLUMNS
1040
OPTIONAL OBJECTS
1015
INDEX
1030
RESULTS
1025
COMPOUND QUERY EXPRESSION
1050
MULTIPLE SET/GET METHODS
1070
MULTIPLE EXECUTE METHODS
1090
MULTIPLE CTE METHODS
1060
MULTIPLE RENDERING METHODS
1080
MULTIPLE CREATE STRUCTURED LANGUAGE STRINGS

FIG.10

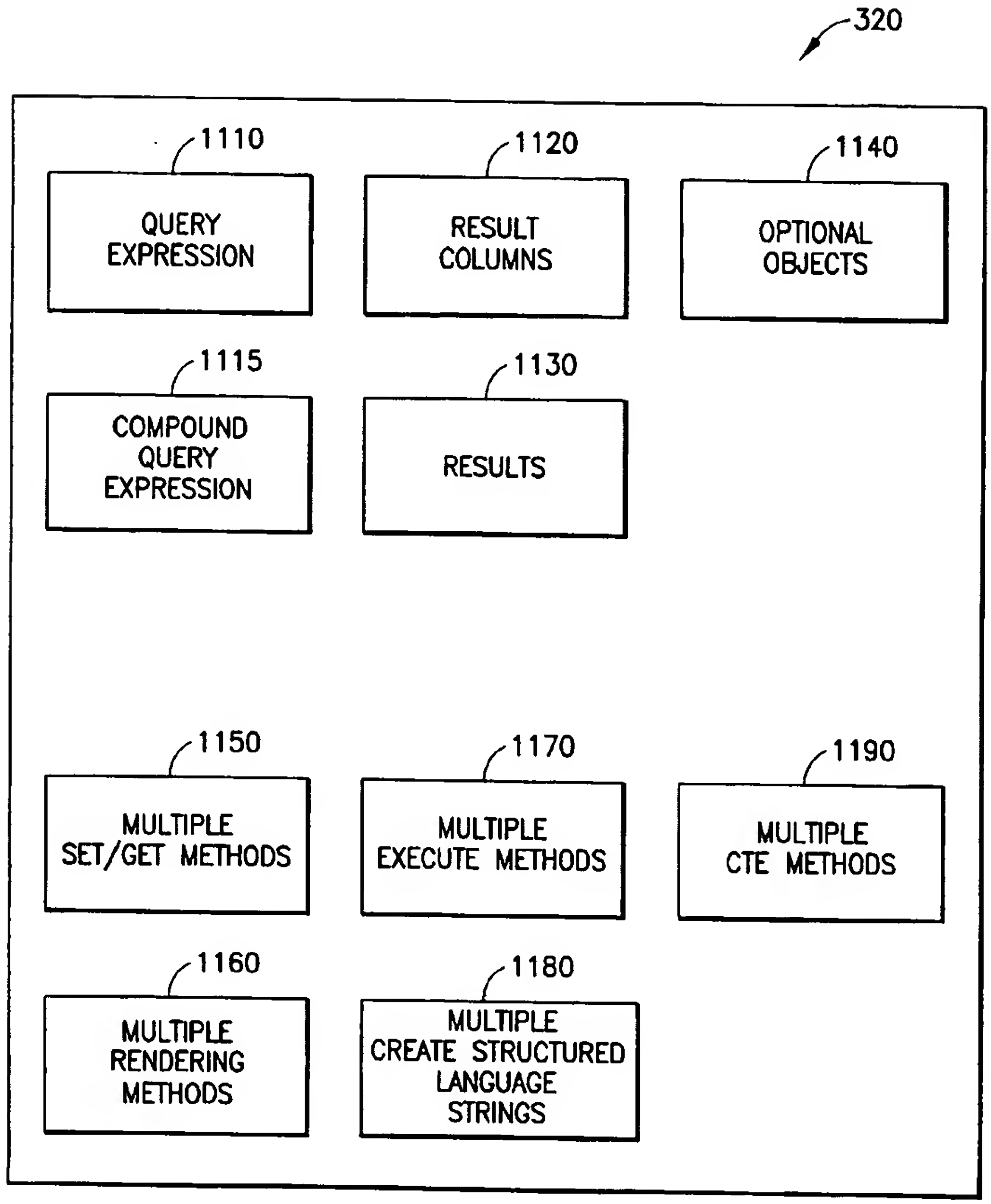

320
1110
QUERY EXPRESSION
1120
RESULT COLUMNS
1140
OPTIONAL OBJECTS
1115
COMPOUND QUERY EXPRESSION
1130
RESULTS
1150
MULTIPLE SET/GET METHODS
1170
MULTIPLE EXECUTE METHODS
1190
MULTIPLE CTE METHODS
1160
MULTIPLE RENDERING METHODS
1180
MULTIPLE CREATE STRUCTURED LANGUAGE STRINGS

FIG.11

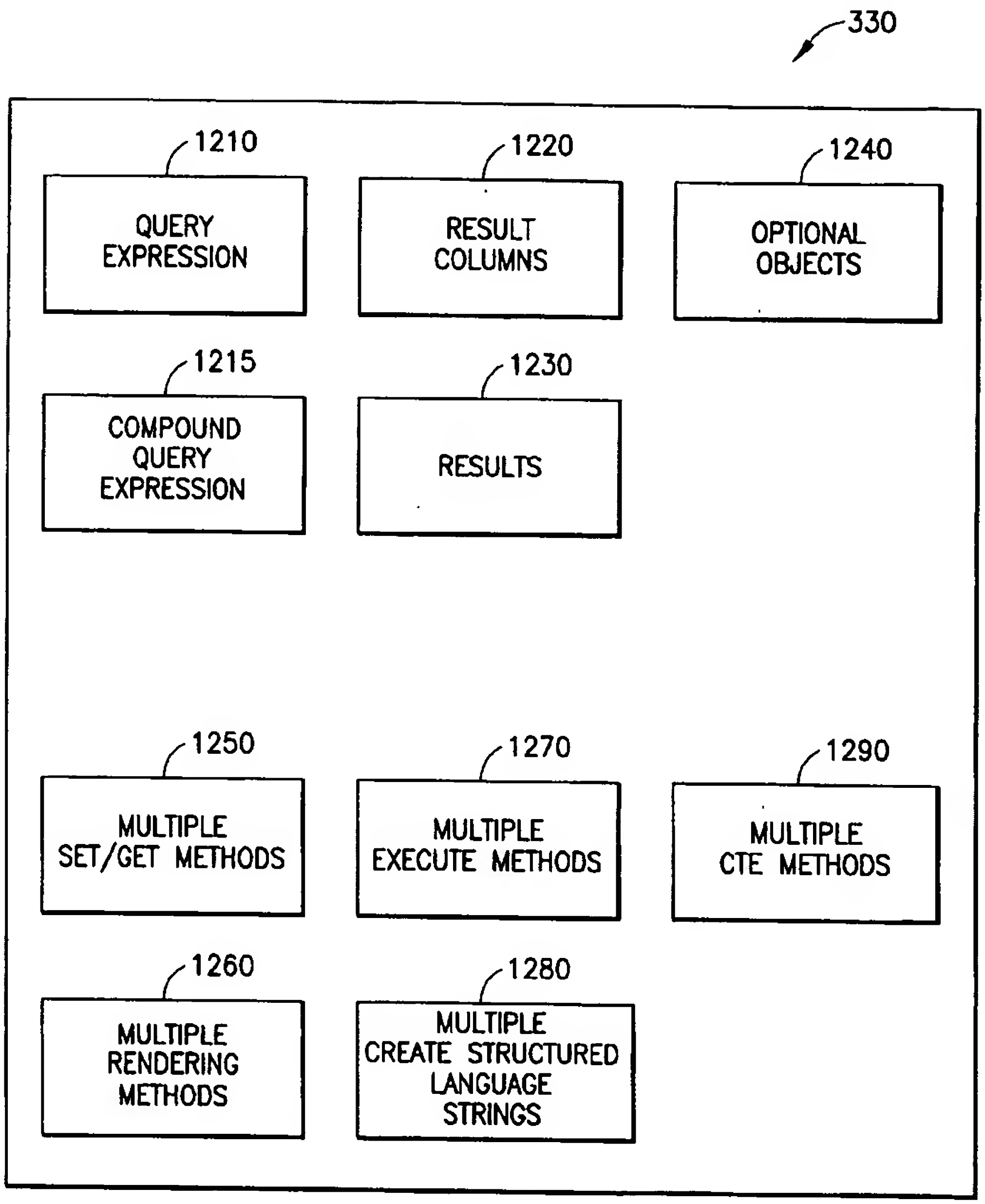

330
1210
QUERY EXPRESSION
1220
RESULT COLUMNS
1240
OPTIONAL OBJECTS
1215
COMPOUND QUERY EXPRESSION
1230
RESULTS
1250
MULTIPLE SET/GET METHODS
1270
MULTIPLE EXECUTE METHODS
1290
MULTIPLE CTE METHODS
1260
MULTIPLE RENDERING METHODS
1280
MULTIPLE CREATE STRUCTURED LANGUAGE STRINGS

FIG.12

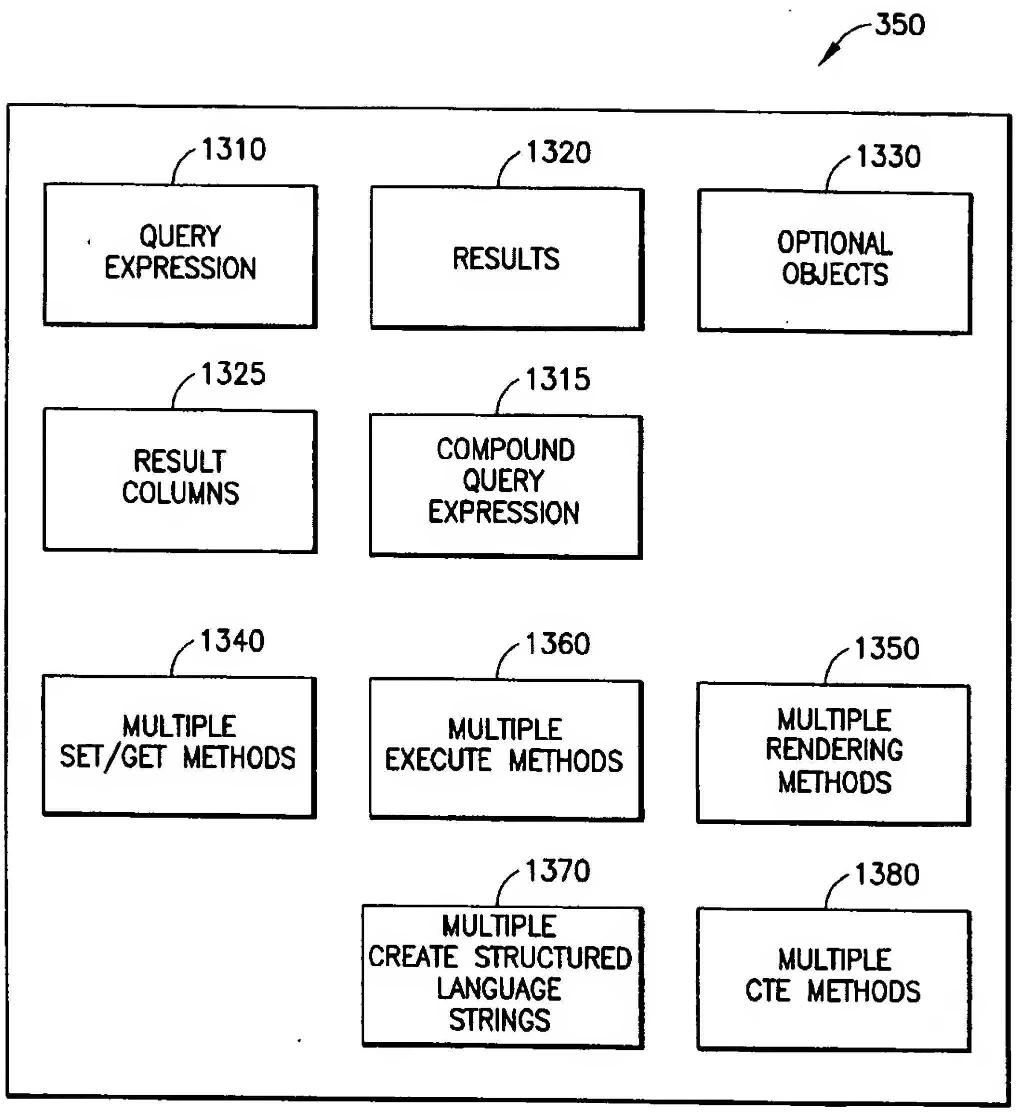

350
1310
QUERY EXPRESSION
1320
RESULTS
1330
OPTIONAL OBJECTS
1325
RESULT COLUMNS
1315
COMPOUND QUERY EXPRESSION
1340
MULTIPLE SET/GET METHODS
1360
MULTIPLE EXECUTE METHODS
1350
MULTIPLE RENDERING METHODS
1370
MULTIPLE CREATE STRUCTURED LANGUAGE STRINGS
1380
MULTIPLE CTE METHODS

FIG.13

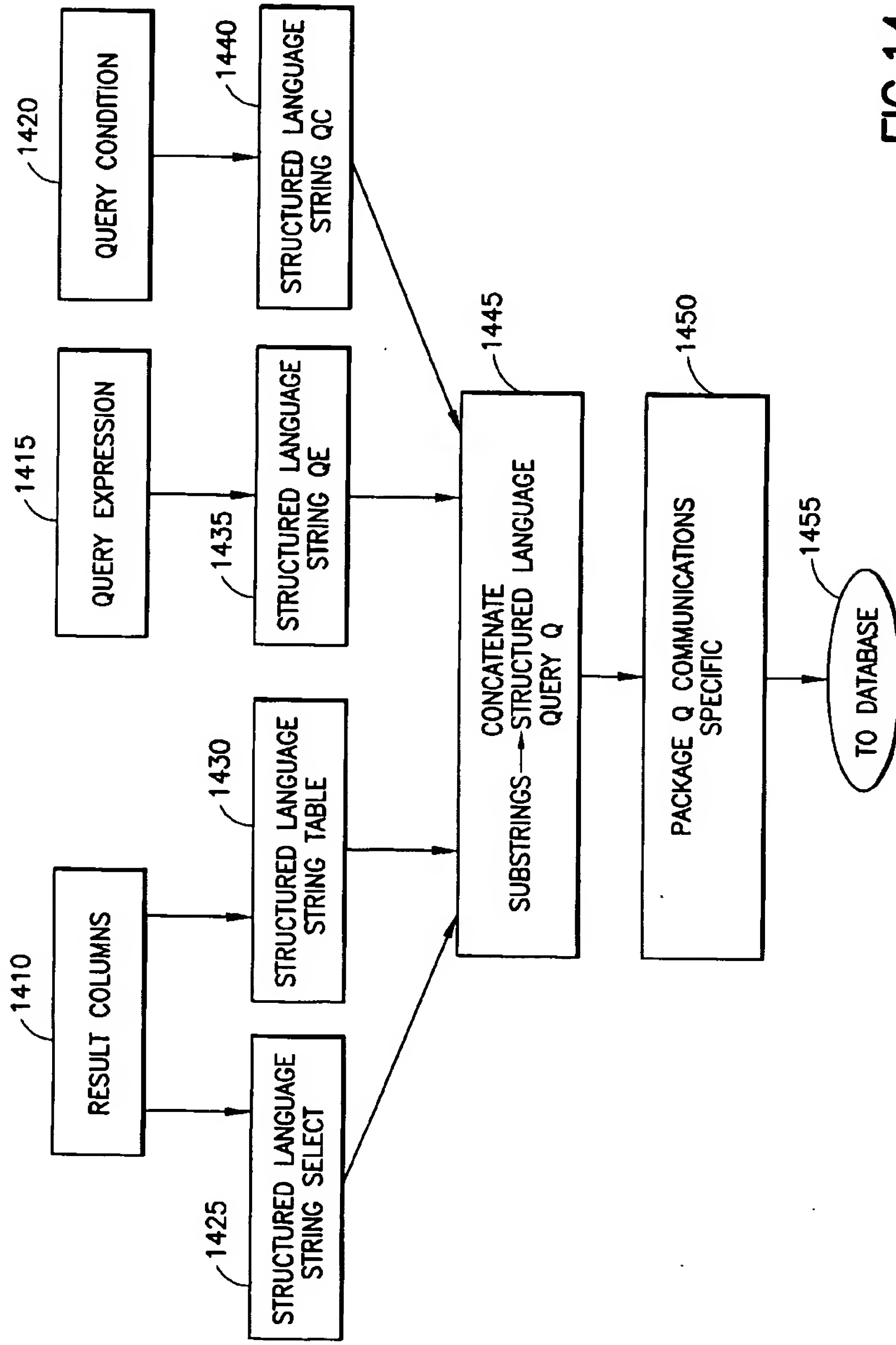

1410
RESULT COLUMNS
1415
QUERY EXPRESSION
1420
QUERY CONDITION
1425
STRUCTURED LANGUAGE STRING SELECT
1430
STRUCTURED LANGUAGE STRING TABLE
1435
STRUCTURED LANGUAGE STRING QE
1440
STRUCTURED LANGUAGE STRING QC
1445
CONCATENATE SUBSTRINGS→STRUCTURED LANGUAGE QUERY Q
1450
PACKAGE Q COMMUNICATIONS SPECIFIC
1455
TO DATABASE

FIG.14

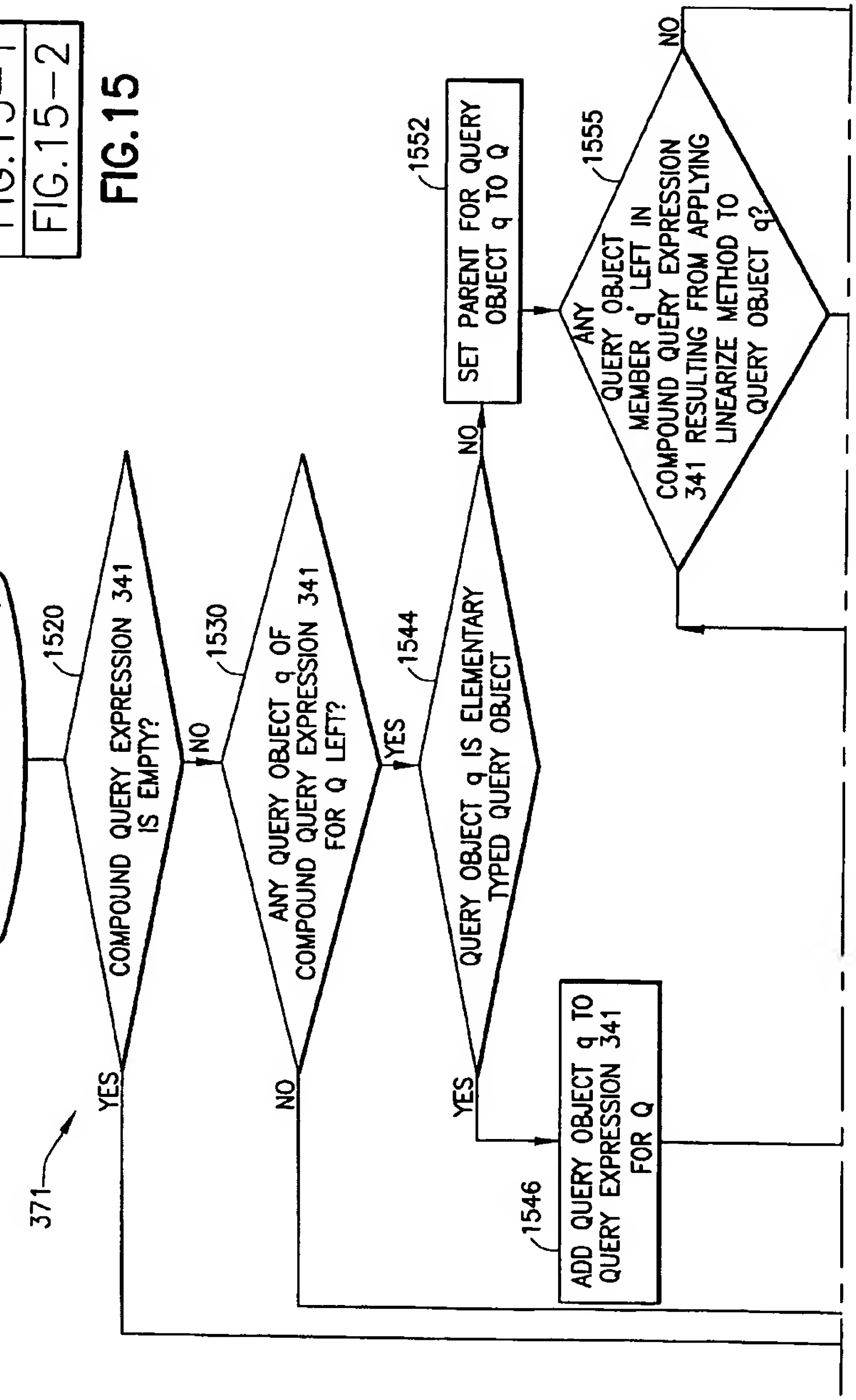


FIG.15-1
FIG.15-2
FIG.15
371
A GIVEN QUERY OBJECT Q
1520
COMPOUND QUERY EXPRESSION 341 IS EMPTY?
YES
NO
1530
ANY QUERY OBJECT q OF COMPOUND QUERY EXPRESSION 341 FOR Q LEFT?
NO
YES
1544
QUERY OBJECT q IS ELEMENTARY TYPED QUERY OBJECT
YES
NO
1546
ADD QUERY OBJECT q TO QUERY EXPRESSION 341 FOR Q
1552
SET PARENT FOR QUERY OBJECT q TO Q
1555
ANY QUERY OBJECT MEMBER q' LEFT IN COMPOUND QUERY EXPRESSION 341 RESULTING FROM APPLYING LINEARIZE METHOD TO QUERY OBJECT q?
NO

FIG.15-1

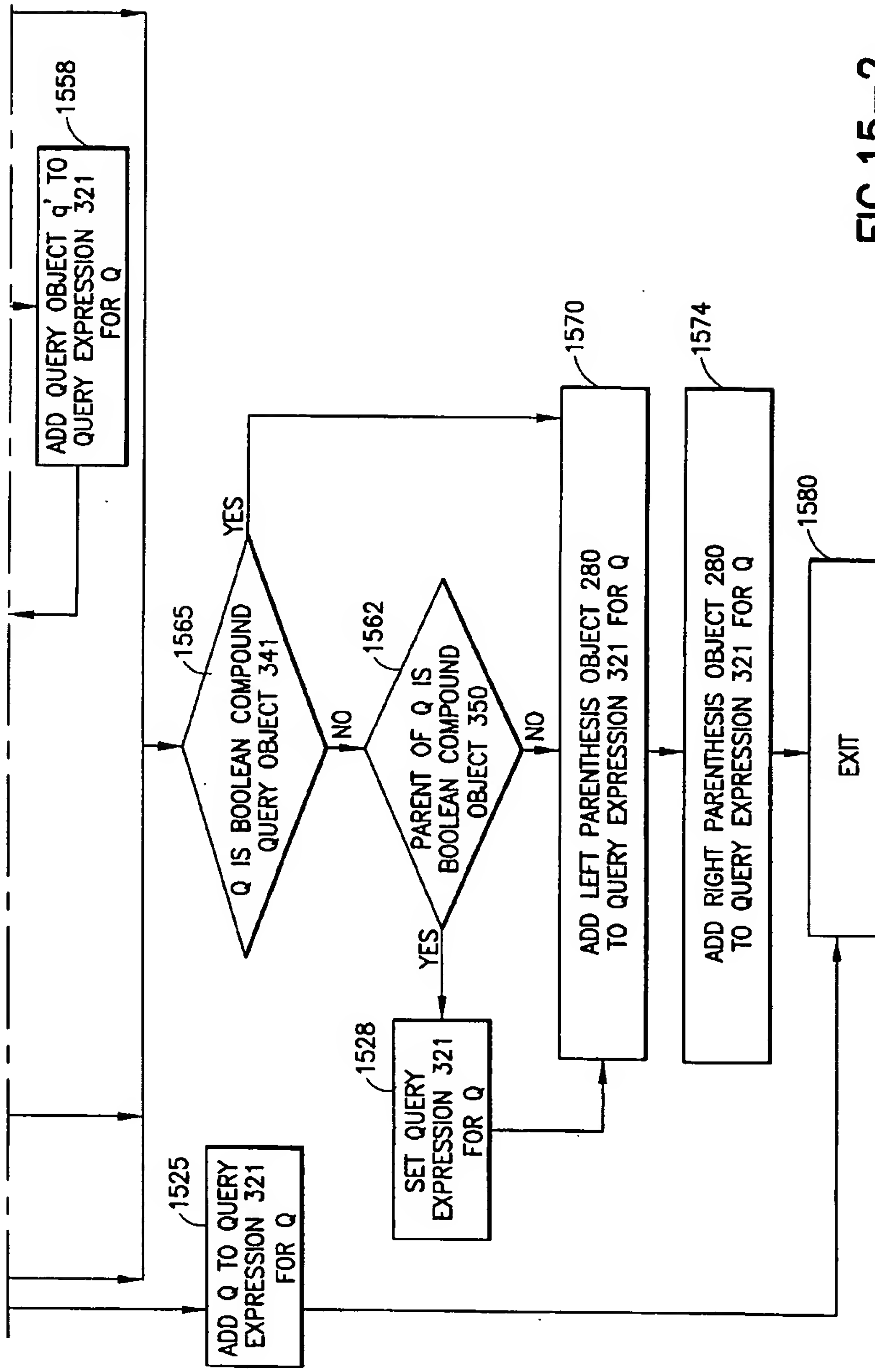

1558
ADD QUERY OBJECT q' TO QUERY EXPRESSION 321 FOR Q
1565
Q IS BOOLEAN COMPOUND QUERY OBJECT 341
YES
NO
1562
PARENT OF Q IS BOOLEAN COMPOUND OBJECT 350
YES
NO
1528
SET QUERY EXPRESSION 321 FOR Q
1525
ADD Q TO QUERY EXPRESSION 321 FOR Q
1570
ADD LEFT PARENTHESIS OBJECT 280 TO QUERY EXPRESSION 321 FOR Q
1574
ADD RIGHT PARENTHESIS OBJECT 280 TO QUERY EXPRESSION 321 FOR Q
1580
EXIT

FIG.15-2

(((("Bill Clinton" & visit & China) or ("Bill Clinton" & Bosnia)) &
((Video Title=ABC Nightly News) & (Air Date=Sep 9 1998))) &
((Motion=Zoom in) & (Faces=1)))

FIG.15A

(1 COMPOUND BOOLEAN QUERY OBJECT, 350
(2 COMPOUND BOOLEAN QUERY OBJECT, 350
(2.1 COMPOUND BOOLEAN TEXT QUERY OBJECT, 350
(2.1.1 COMPOUND BOOLEAN TEXT QUERY OBJECT, 300 "Bill Clinton" & visit & China) OR (2.1.2 COMPOUND BOOLEAN TEXT QUERY OBJECT, 300 "Bill Clinton" & Bosnia)
&
(2.2 PARAMETRIC COMPOUND QUERY OBJECT
(2.2.1 Video Title=ABC Nightly News) & (2.2.2 Air Date=Sep 9 1998))
)
&
(3 COMPOUND FEATURE QUERY OBJECT
(3.1.1 Motion=Zoom in) & (3.1.2 Faces=1))
)

FIG.15B

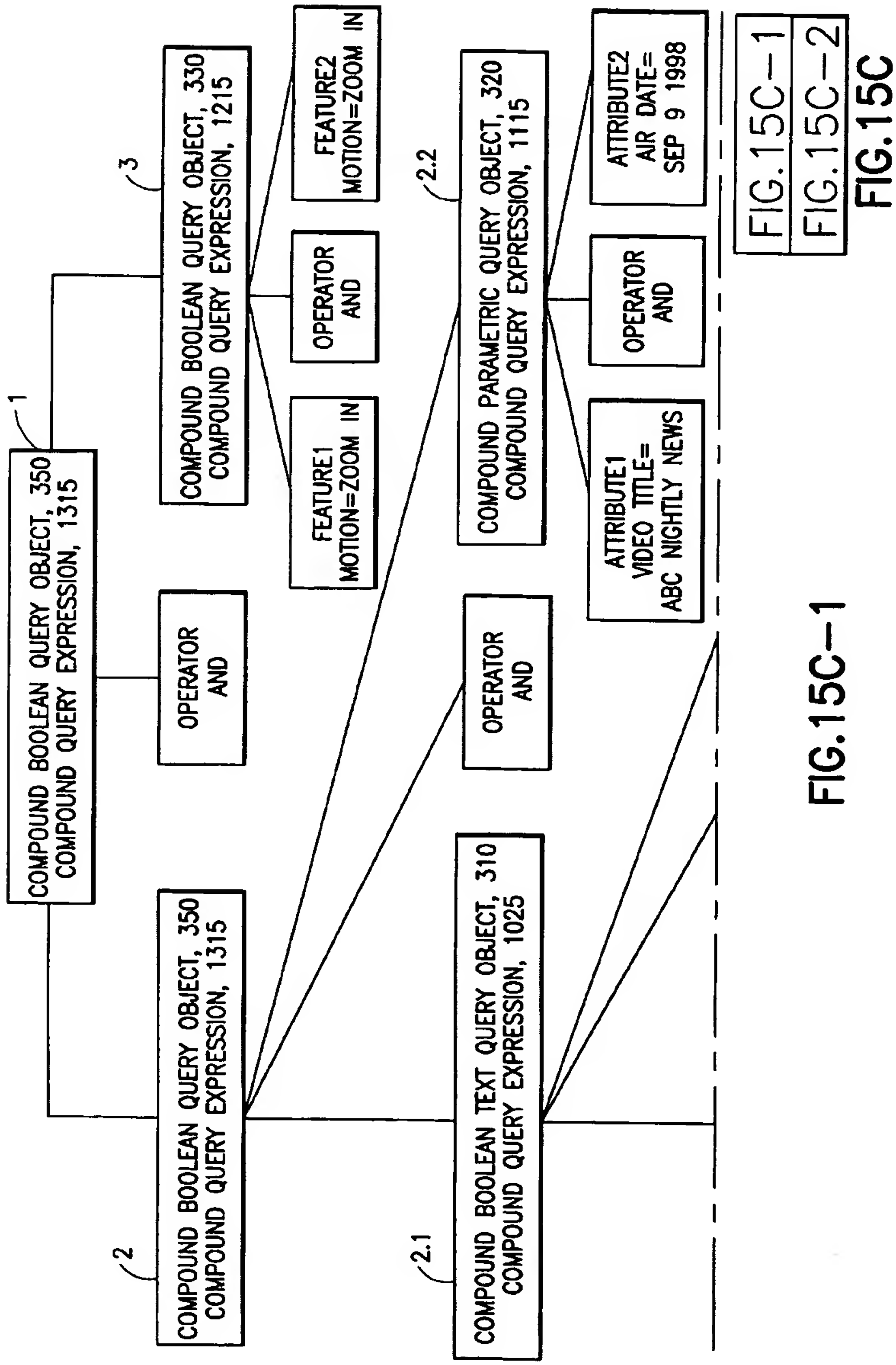

1
COMPOUND BOOLEAN QUERY OBJECT, 350
COMPOUND QUERY EXPRESSION, 1315
OPERATOR
AND
2
COMPOUND BOOLEAN QUERY OBJECT, 350
COMPOUND QUERY EXPRESSION, 1315
3
COMPOUND BOOLEAN QUERY OBJECT, 330
COMPOUND QUERY EXPRESSION, 1215
FEATURE1
MOTION=ZOOM IN
OPERATOR
AND
FEATURE2
MOTION=ZOOM IN
2.1
COMPOUND BOOLEAN TEXT QUERY OBJECT, 310
COMPOUND QUERY EXPRESSION, 1025
OPERATOR
AND
2.2
COMPOUND PARAMETRIC QUERY OBJECT, 320
COMPOUND QUERY EXPRESSION, 1115
ATTRIBUTE1
VIDEO TITLE=
ABC NIGHTLY NEWS
OPERATOR
AND
ATTRIBUTE2
AIR DATE=
SEP 9 1998
FIG.15C–1
FIG.15C–2
FIG.15C

FIG.15C–1

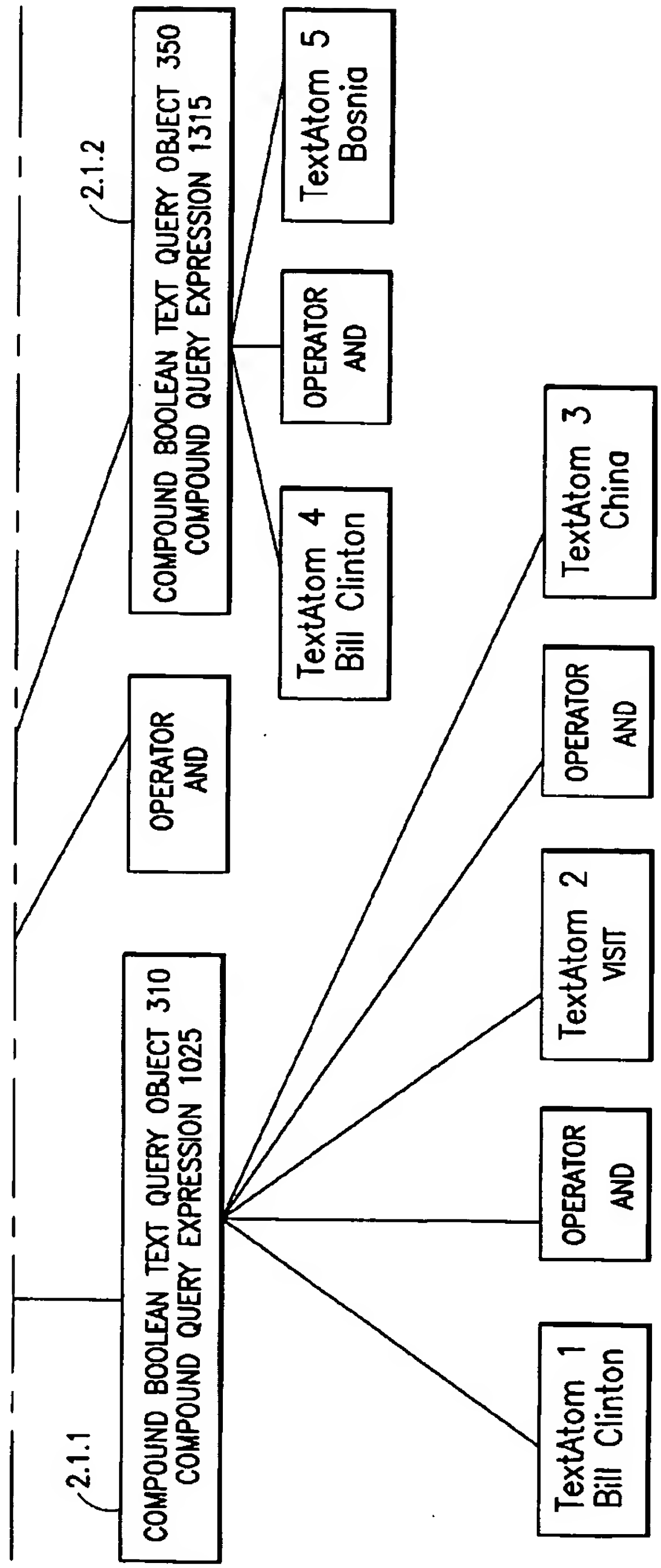

2.1.2
COMPOUND BOOLEAN TEXT QUERY OBJECT 350
COMPOUND QUERY EXPRESSION 1315
TextAtom 5
Bosnia
OPERATOR
AND
TextAtom 4
Bill Clinton
OPERATOR
AND
TextAtom 3
China
OPERATOR
AND
TextAtom 2
VISIT
OPERATOR
AND
2.1.1
COMPOUND BOOLEAN TEXT QUERY OBJECT 310
COMPOUND QUERY EXPRESSION 1025
TextAtom 1
Bill Clinton

FIG.15C–2

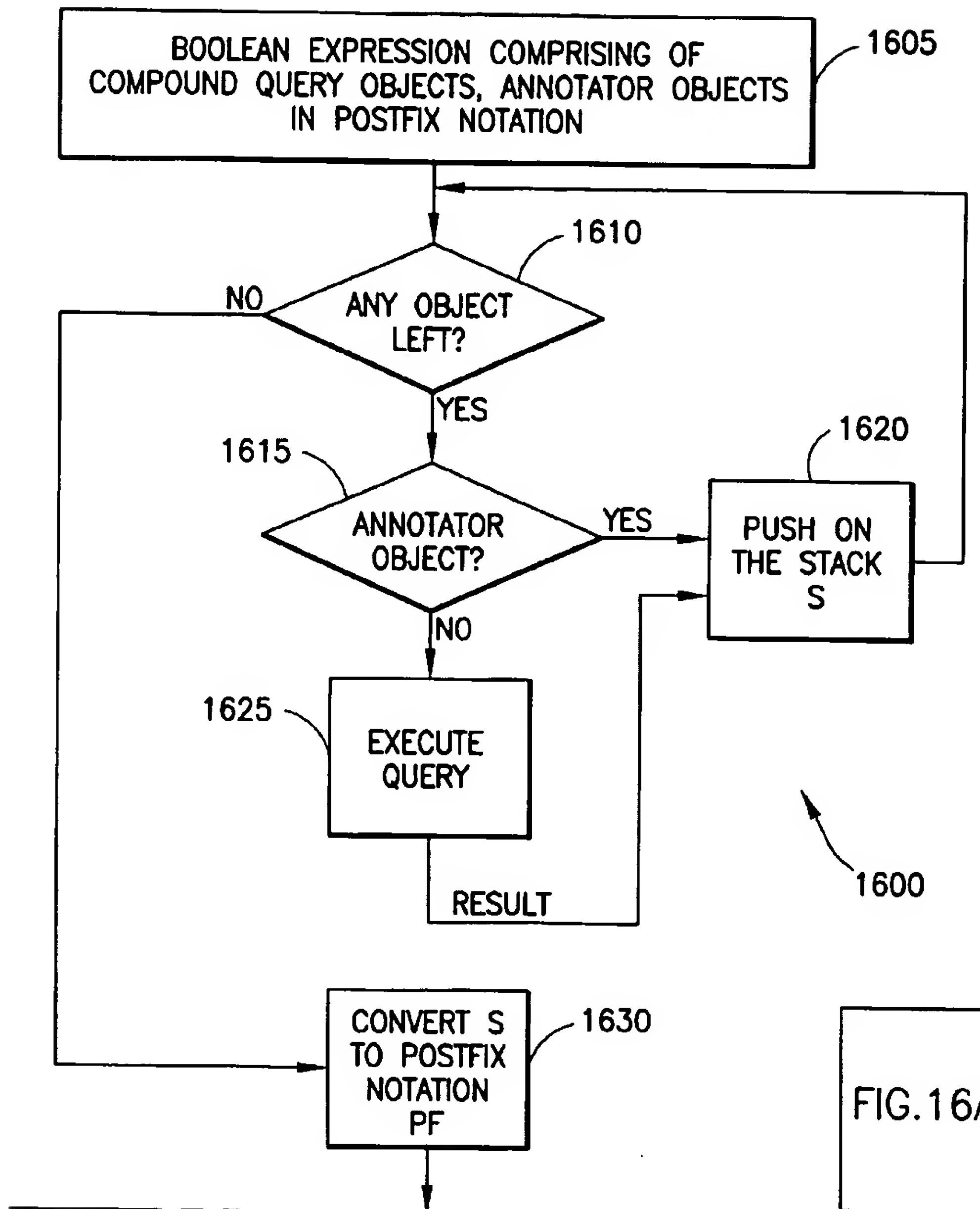


FIG.16A

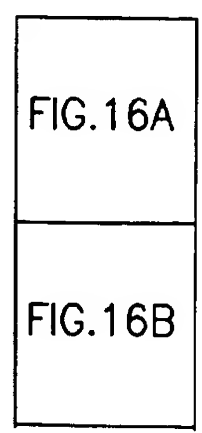
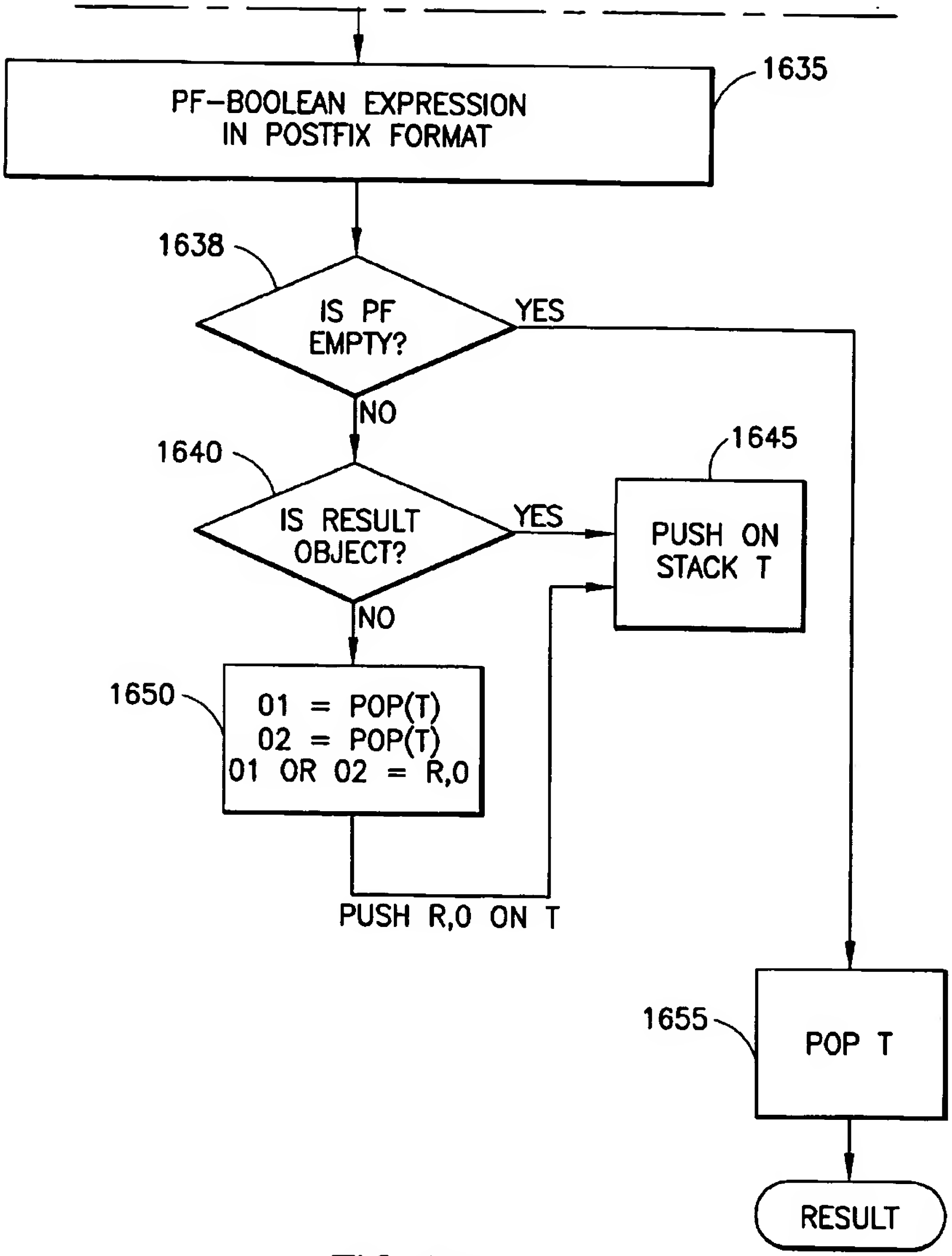
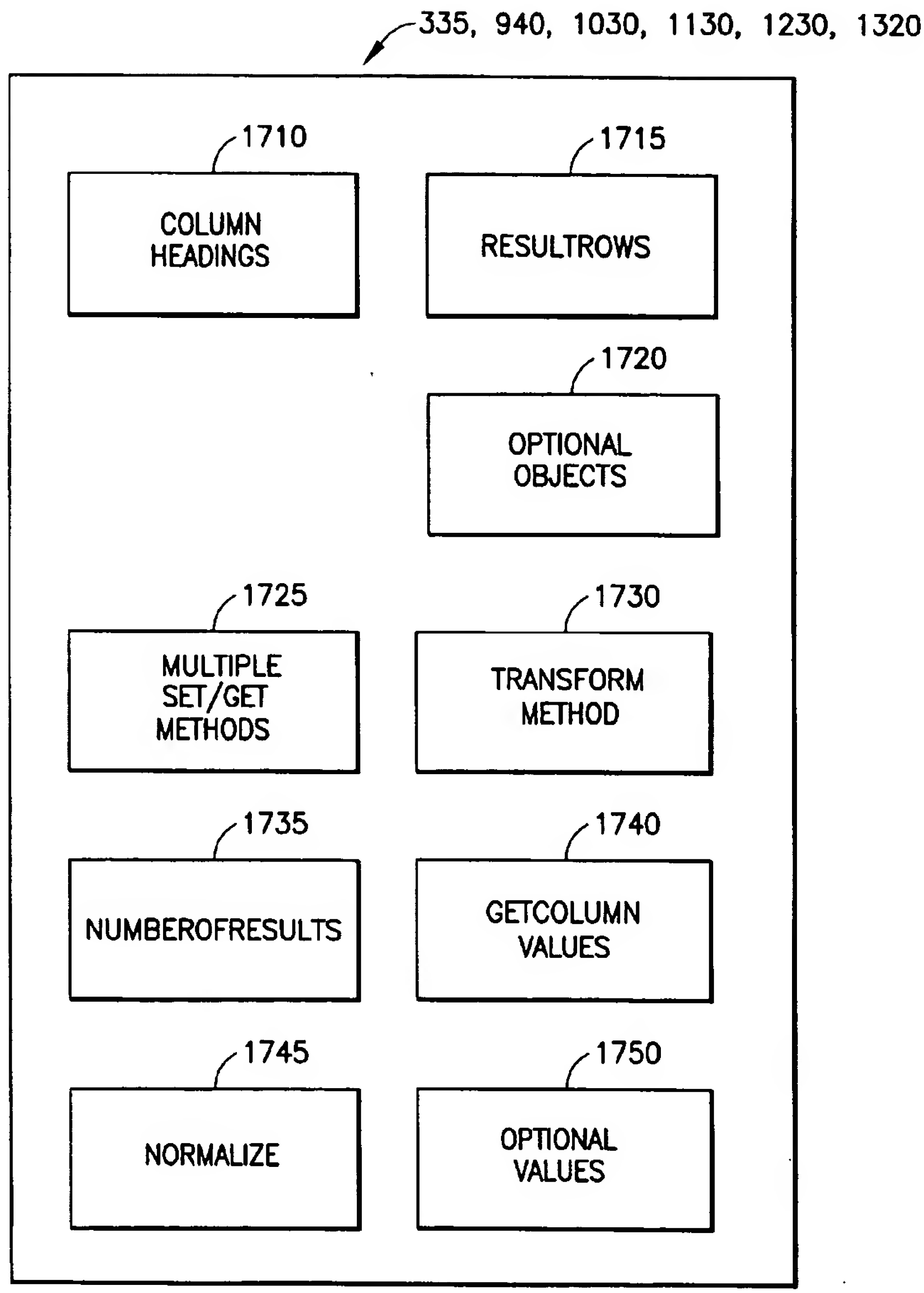


FIG.16



PF-BOOLEAN EXPRESSION IN POSTFIX FORMAT
1635
1638
IS PF EMPTY?
YES
NO
1640
IS RESULT OBJECT?
YES
1645
PUSH ON STACK T
NO
1650
01 = POP(T)
02 = POP(T)
01 OR 02 = R,0
PUSH R,0 ON T
1655
POP T
RESULT

FIG.16B



335, 940, 1030, 1130, 1230, 1320
1710
COLUMN HEADINGS
1715
RESULTROWS
1720
OPTIONAL OBJECTS
1725
MULTIPLE SET/GET METHODS
1730
TRANSFORM METHOD
1735
NUMBEROFRESULTS
1740
GETCOLUMN VALUES
1745
NORMALIZE
1750
OPTIONAL VALUES

FIG.17

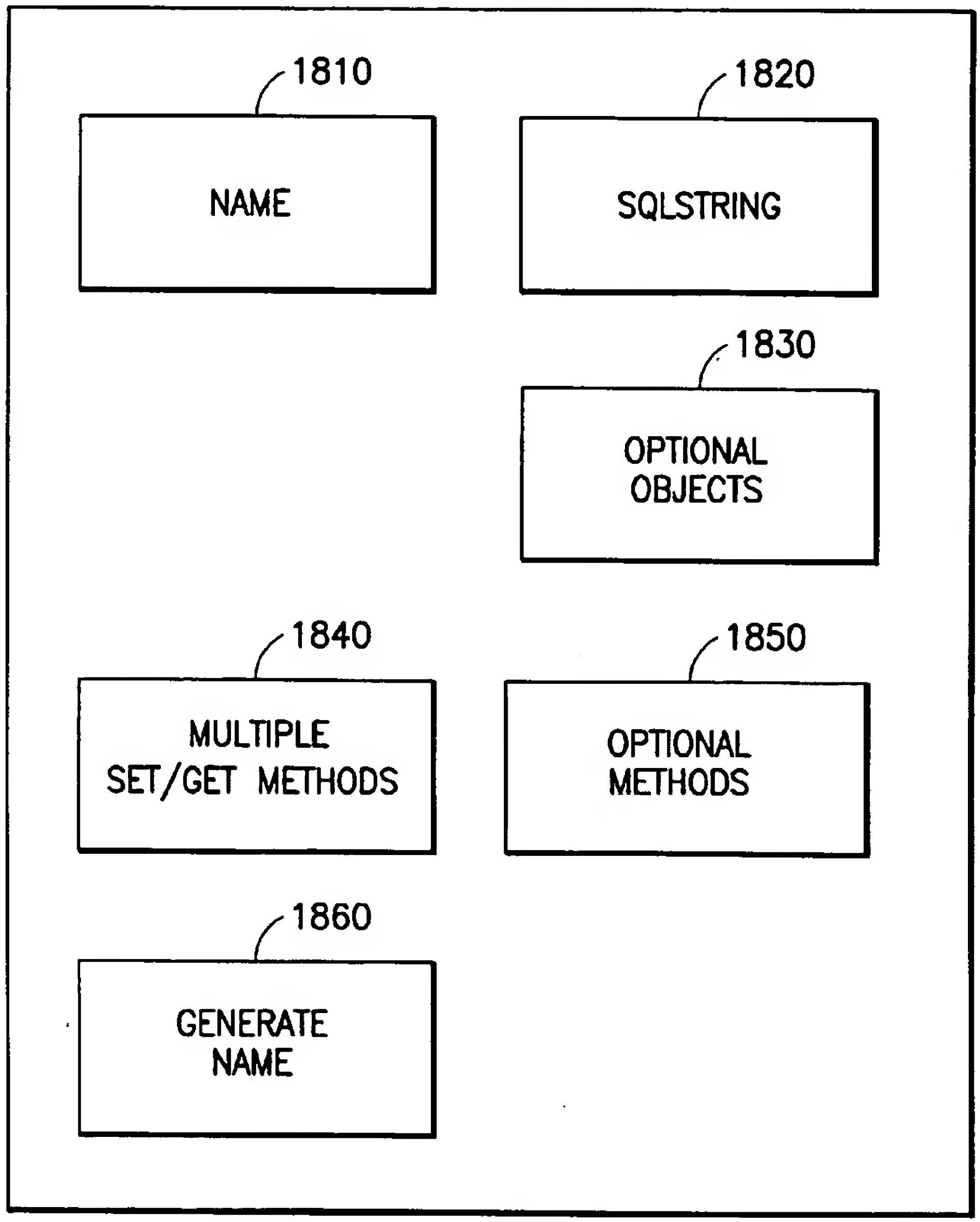

1810
NAME
1820
SQLSTRING
1830
OPTIONAL OBJECTS
1840
MULTIPLE SET/GET METHODS
1850
OPTIONAL METHODS
1860
GENERATE NAME

FIG.18

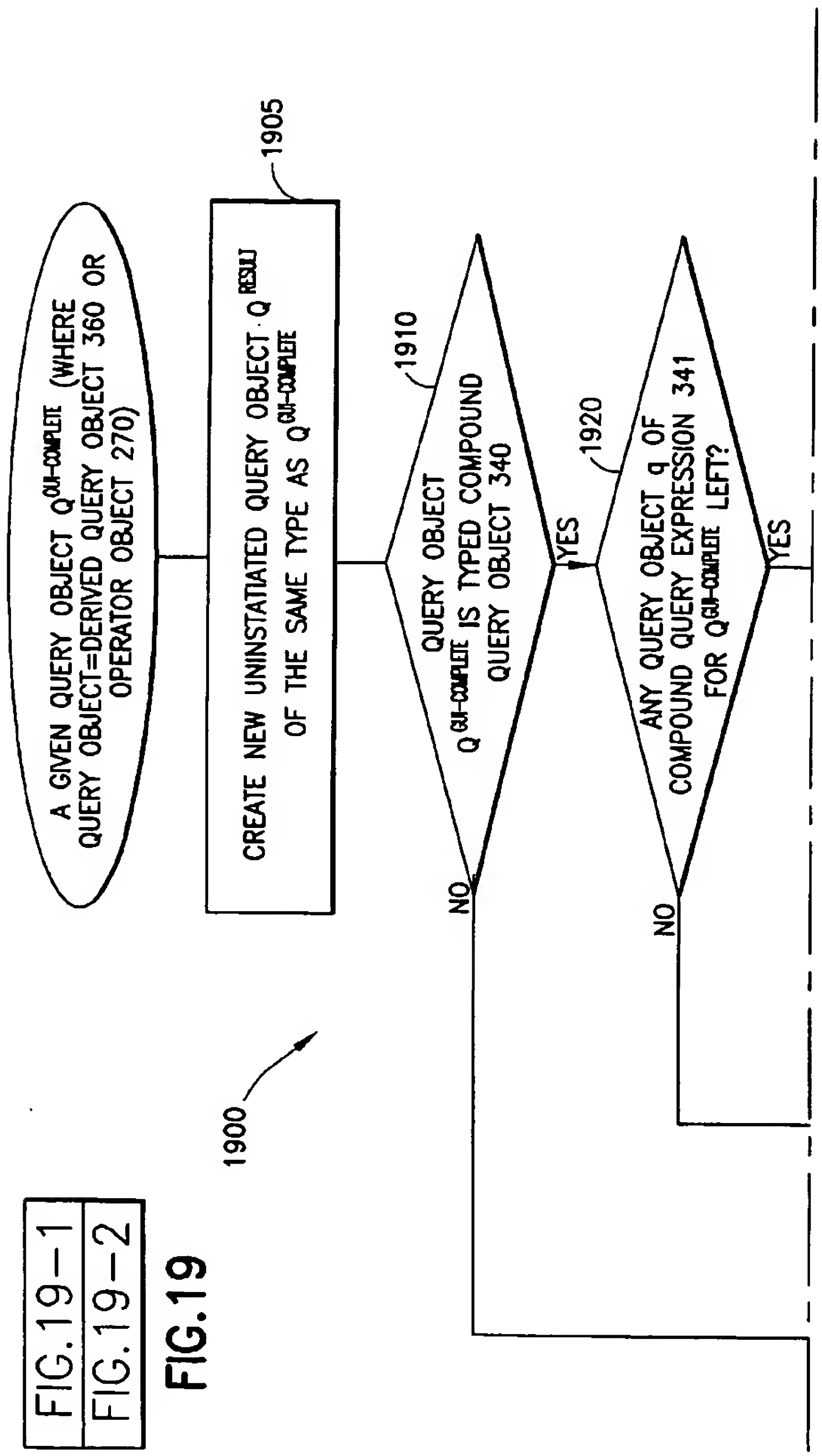
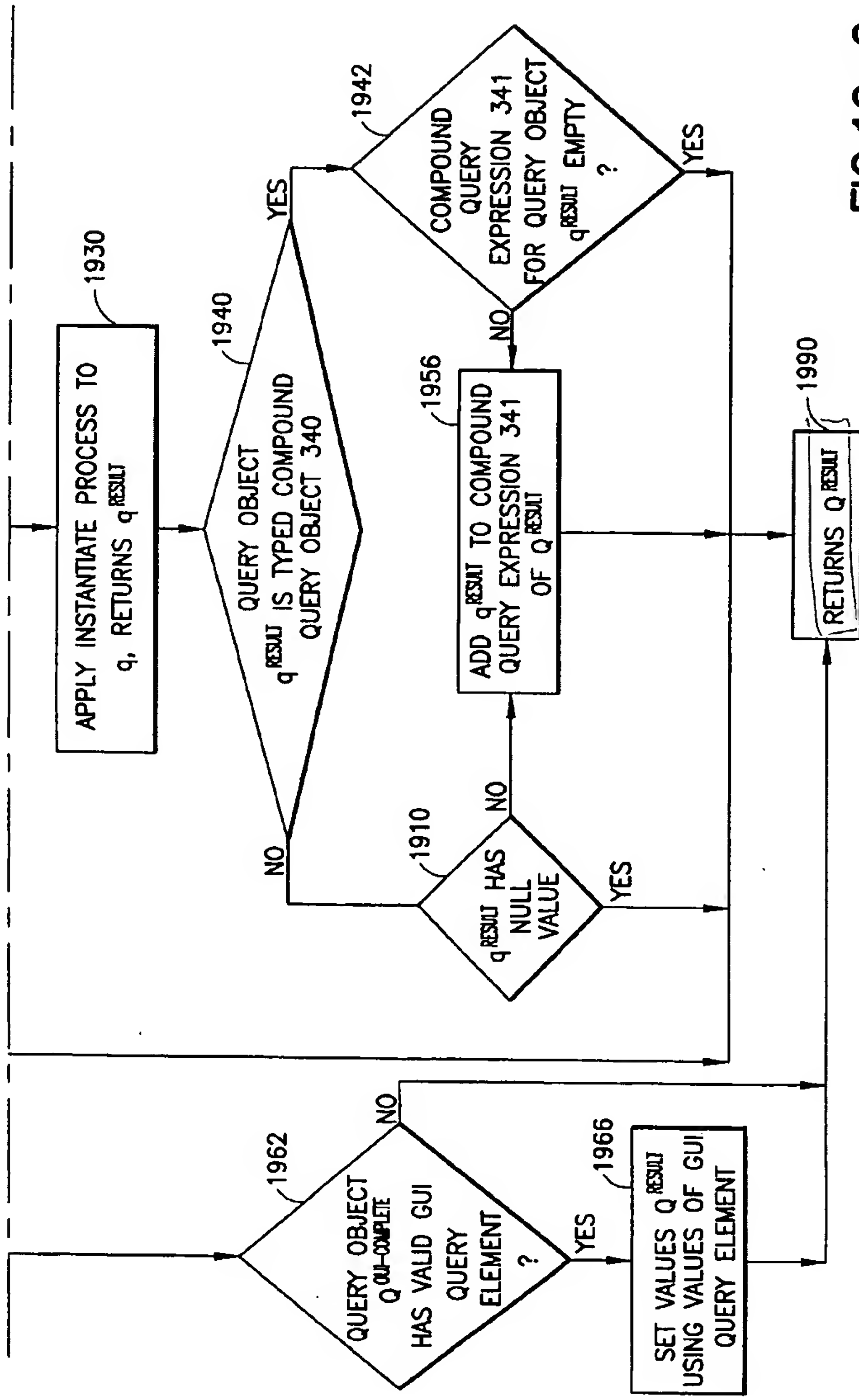

A GIVEN QUERY OBJECT Q^GUI-COMPLETE (WHERE QUERY OBJECT=DERIVED QUERY OBJECT 360 OR OPERATOR OBJECT 270)
1905
CREATE NEW UNINSTATIATED QUERY OBJECT Q^RESULT OF THE SAME TYPE AS Q^GUI-COMPLETE
1910
QUERY OBJECT Q^GUI-COMPLETE IS TYPED COMPOUND QUERY OBJECT 340
YES
NO
1920
ANY QUERY OBJECT q OF COMPOUND QUERY EXPRESSION 341 FOR Q^GUI-COMPLETE LEFT?
YES
NO
1900
FIG.19-1
FIG.19-2
FIG.19

FIG.19-1



APPLY INSTANTIATE PROCESS TO q, RETURNS q RESULT
1930
QUERY OBJECT q RESULT IS TYPED COMPOUND QUERY OBJECT 340
1940
YES
NO
COMPOUND QUERY EXPRESSION 341 FOR QUERY OBJECT q RESULT EMPTY ?
1942
YES
NO
ADD q RESULT TO COMPOUND QUERY EXPRESSION 341 OF Q RESULT
1956
q RESULT HAS NULL VALUE
1910
NO
YES
RETURNS Q RESULT
1990
QUERY OBJECT Q GUI-COMPLETE HAS VALID GUI QUERY ELEMENT ?
1962
NO
YES
SET VALUES Q RESULT USING VALUES OF GUI QUERY ELEMENT
1966

FIG.19–2

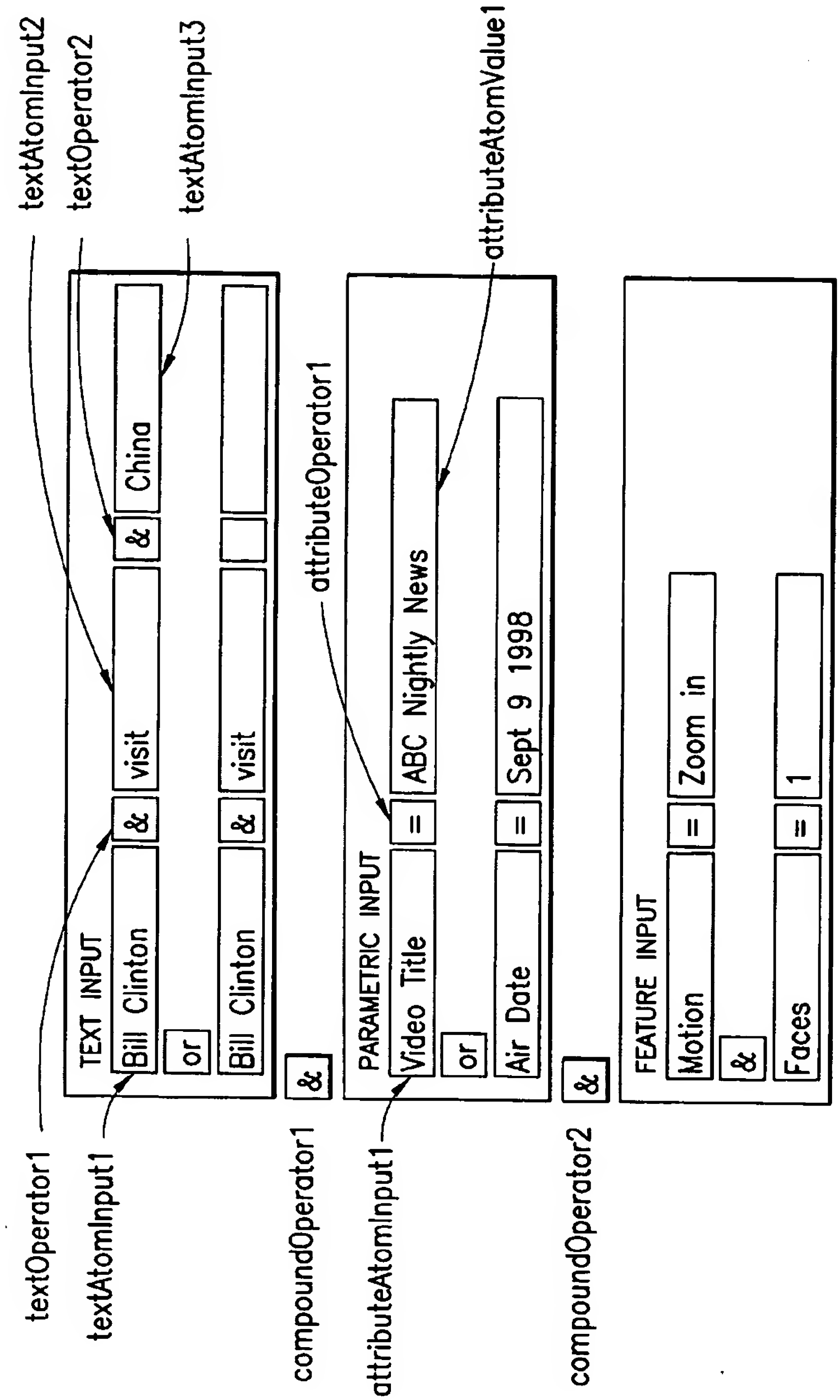

textAtomInput2
textOperator2
textAtomInput3
attributeAtomValue1
TEXT INPUT
Bill Clinton
&
visit
&
China
or
Bill Clinton
&
visit
attributeOperator1
&
PARAMETRIC INPUT
Video Title
=
ABC Nightly News
or
Air Date
=
Sept 9 1998
&
FEATURE INPUT
Motion
=
Zoom in
&
Faces
=
1
textOperator1
textAtomInput1
compoundOperator1
attributeAtomInput1
compoundOperator2

FIG.19A

((("Bill Clinton" & visit & China) or ("Bill Clinton" & Bosnia)) &
((Video Title=ABC Nightly News) & (Air Date=Sep 9 1998))) &
((Motion=Zoom in) & (Faces=1)))

FIG.19B

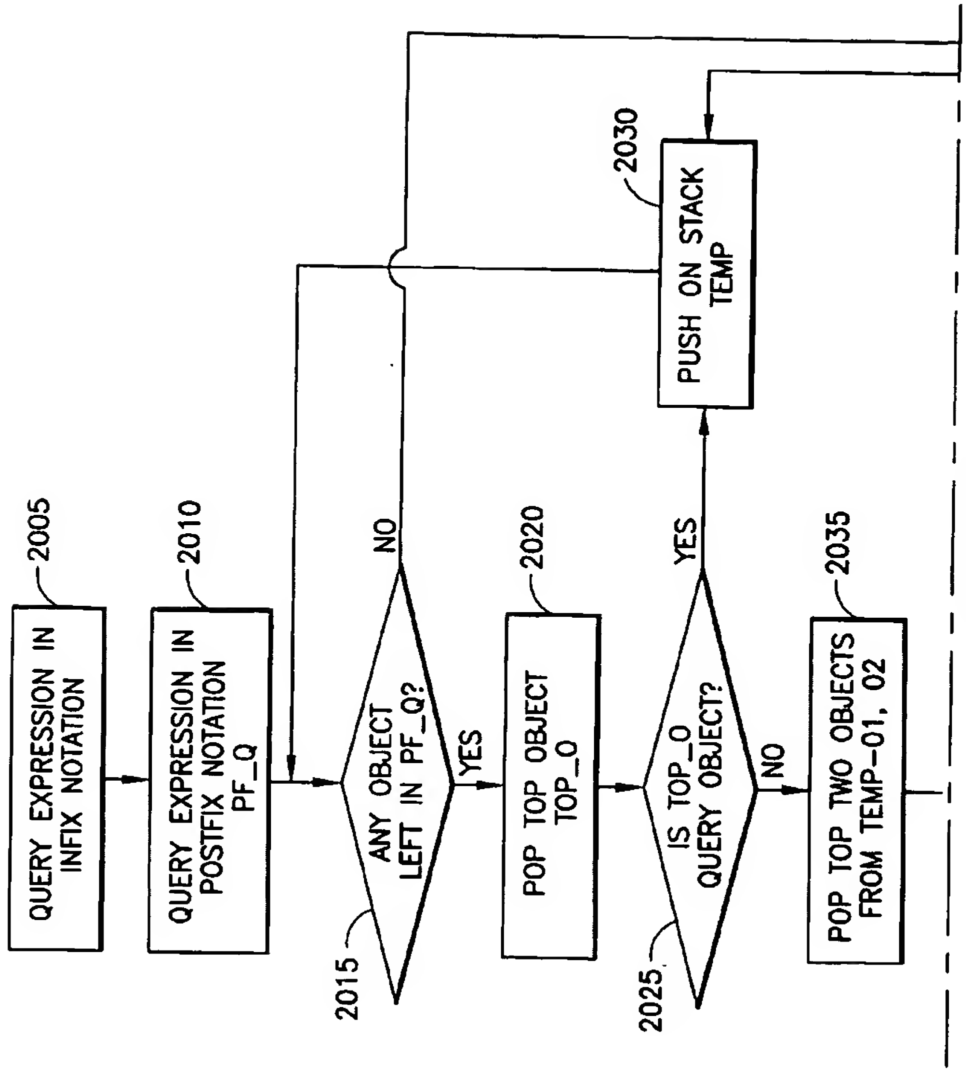


FIG.20A

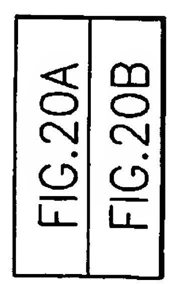


FIG.20

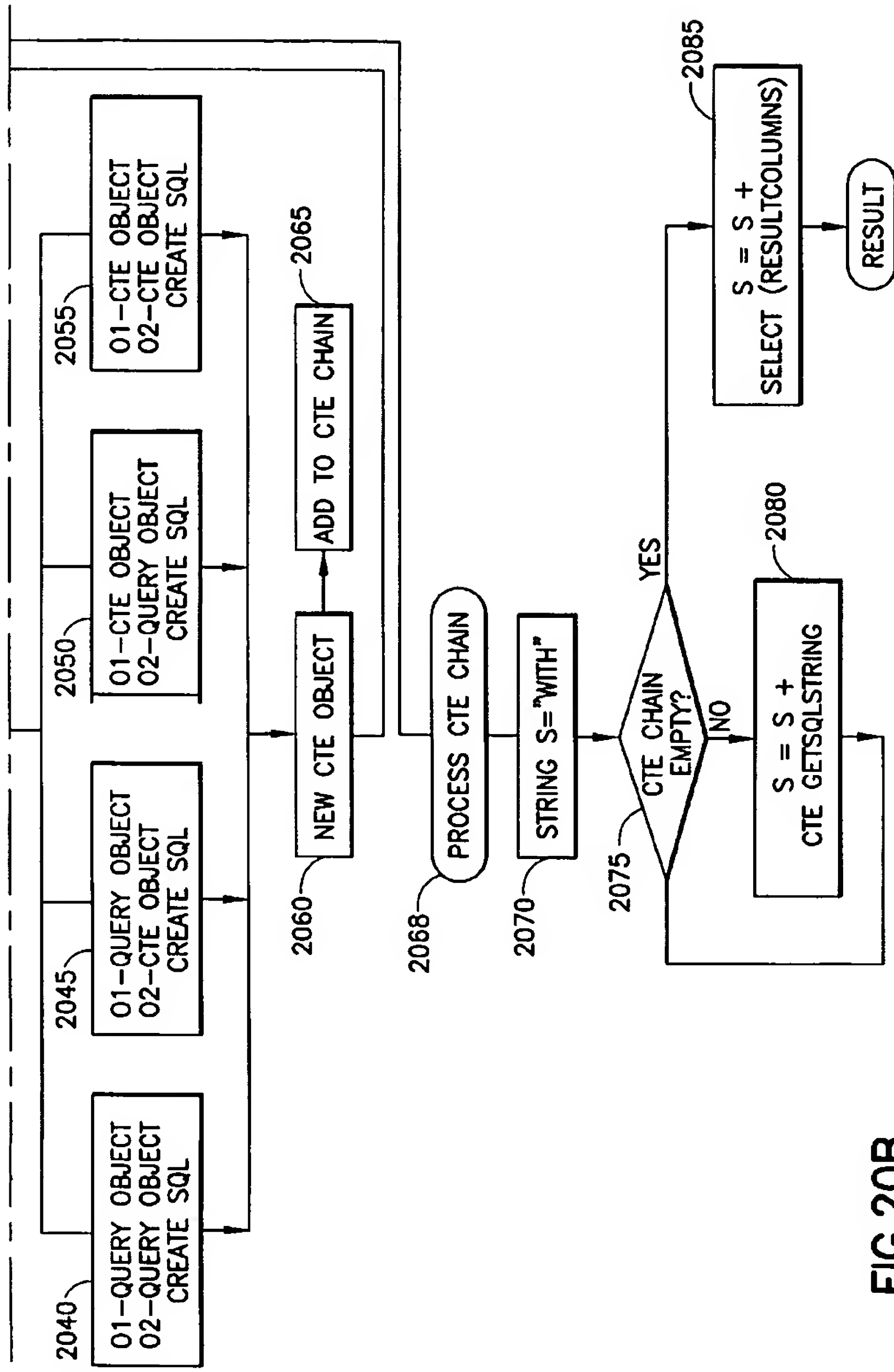

2040
01-QUERY OBJECT
02-QUERY OBJECT
CREATE SQL
2045
01-QUERY OBJECT
02-CTE OBJECT
CREATE SQL
2050
01-CTE OBJECT
02-QUERY OBJECT
CREATE SQL
2055
01-CTE OBJECT
02-CTE OBJECT
CREATE SQL
2060
NEW CTE OBJECT
2065
ADD TO CTE CHAIN
2068
PROCESS CTE CHAIN
2070
STRING S="WITH"
2075
CTE CHAIN EMPTY?
NO
YES
2080
S = S +
CTE GETSQLSTRING
2085
S = S +
SELECT (RESULTCOLUMNS)
RESULT

FIG.20B

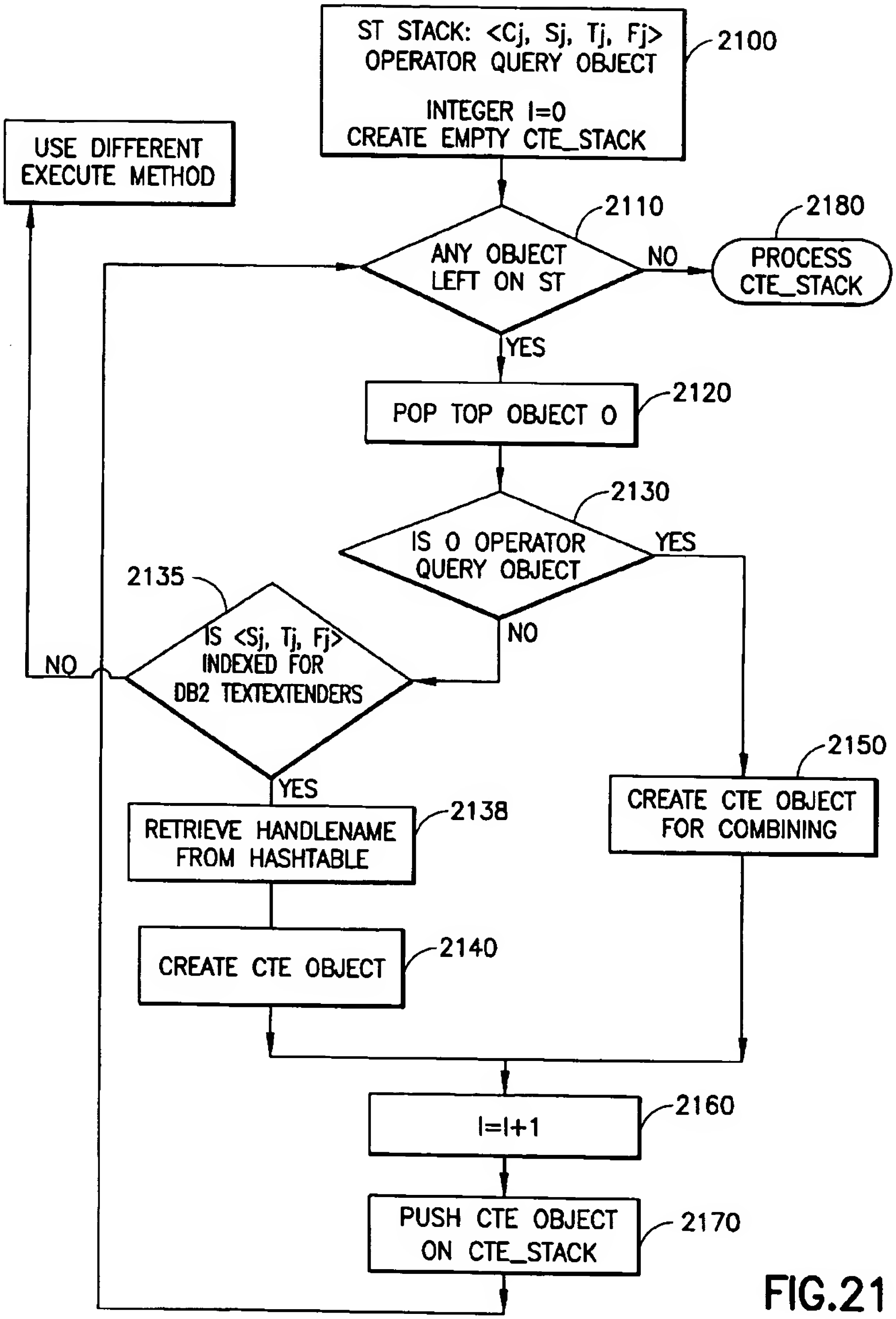

ST STACK: <Cj, Sj, Tj, Fj>
OPERATOR QUERY OBJECT
INTEGER I=0
CREATE EMPTY CTE_STACK
2100
USE DIFFERENT EXECUTE METHOD
2110
ANY OBJECT LEFT ON ST
NO
2180
PROCESS CTE_STACK
YES
POP TOP OBJECT O
2120
2130
IS O OPERATOR QUERY OBJECT
YES
NO
2135
IS <Sj, Tj, Fj> INDEXED FOR DB2 TEXTEXTENDERS
NO
YES
RETRIEVE HANDLENAME FROM HASHTABLE
2138
CREATE CTE OBJECT
2140
2150
CREATE CTE OBJECT FOR COMBINING
I=I+1
2160
PUSH CTE OBJECT ON CTE_STACK
2170

FIG.21

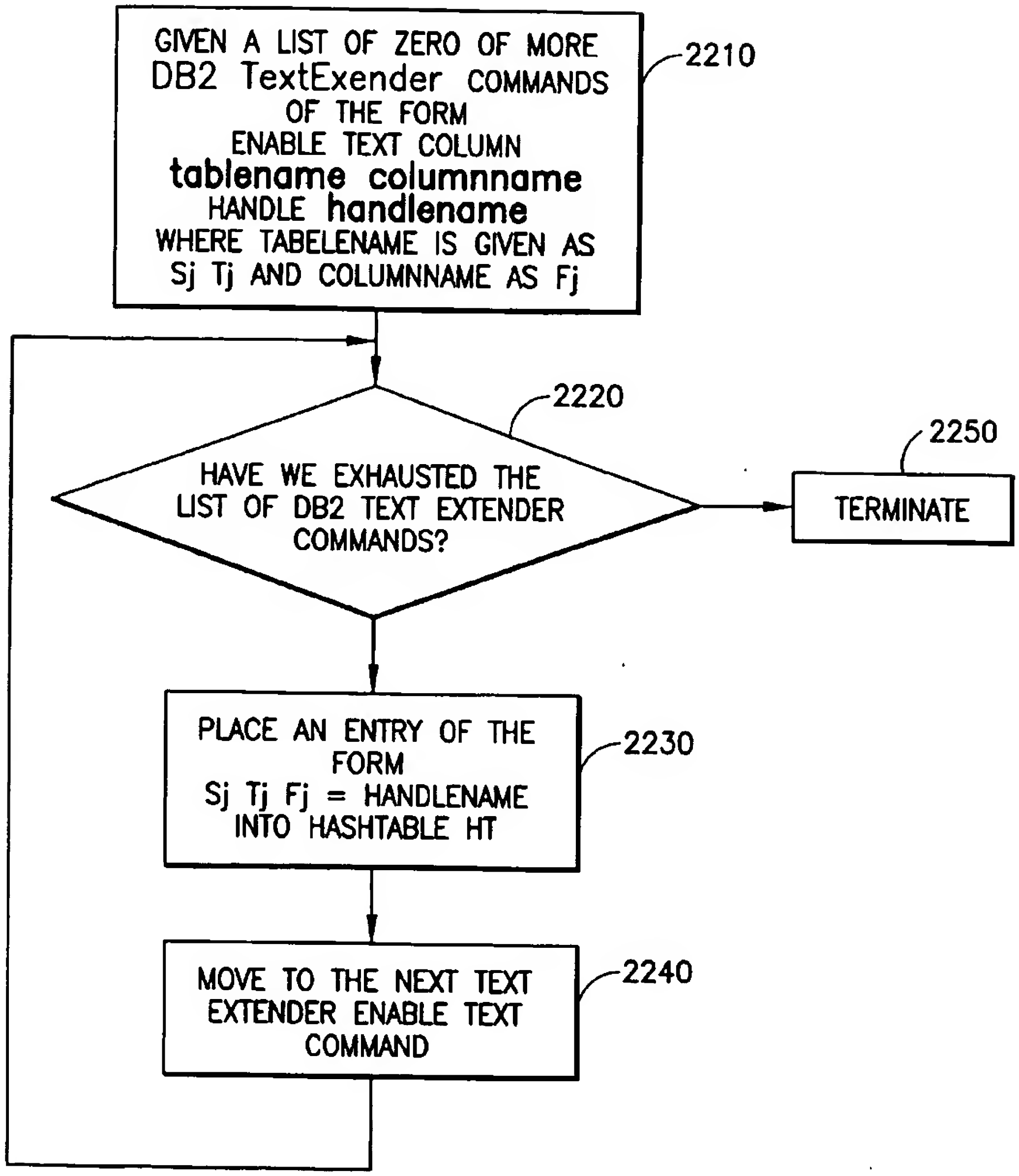

GIVEN A LIST OF ZERO OF MORE DB2 TextExender COMMANDS OF THE FORM ENABLE TEXT COLUMN tablename columnname HANDLE handlename WHERE TABELENAME IS GIVEN AS Sj Tj AND COLUMNNAME AS Fj
2210
HAVE WE EXHAUSTED THE LIST OF DB2 TEXT EXTENDER COMMANDS?
2220
TERMINATE
2250
PLACE AN ENTRY OF THE FORM Sj Tj Fj = HANDLENAME INTO HASHTABLE HT
2230
MOVE TO THE NEXT TEXT EXTENDER ENABLE TEXT COMMAND
2240

FIG.22

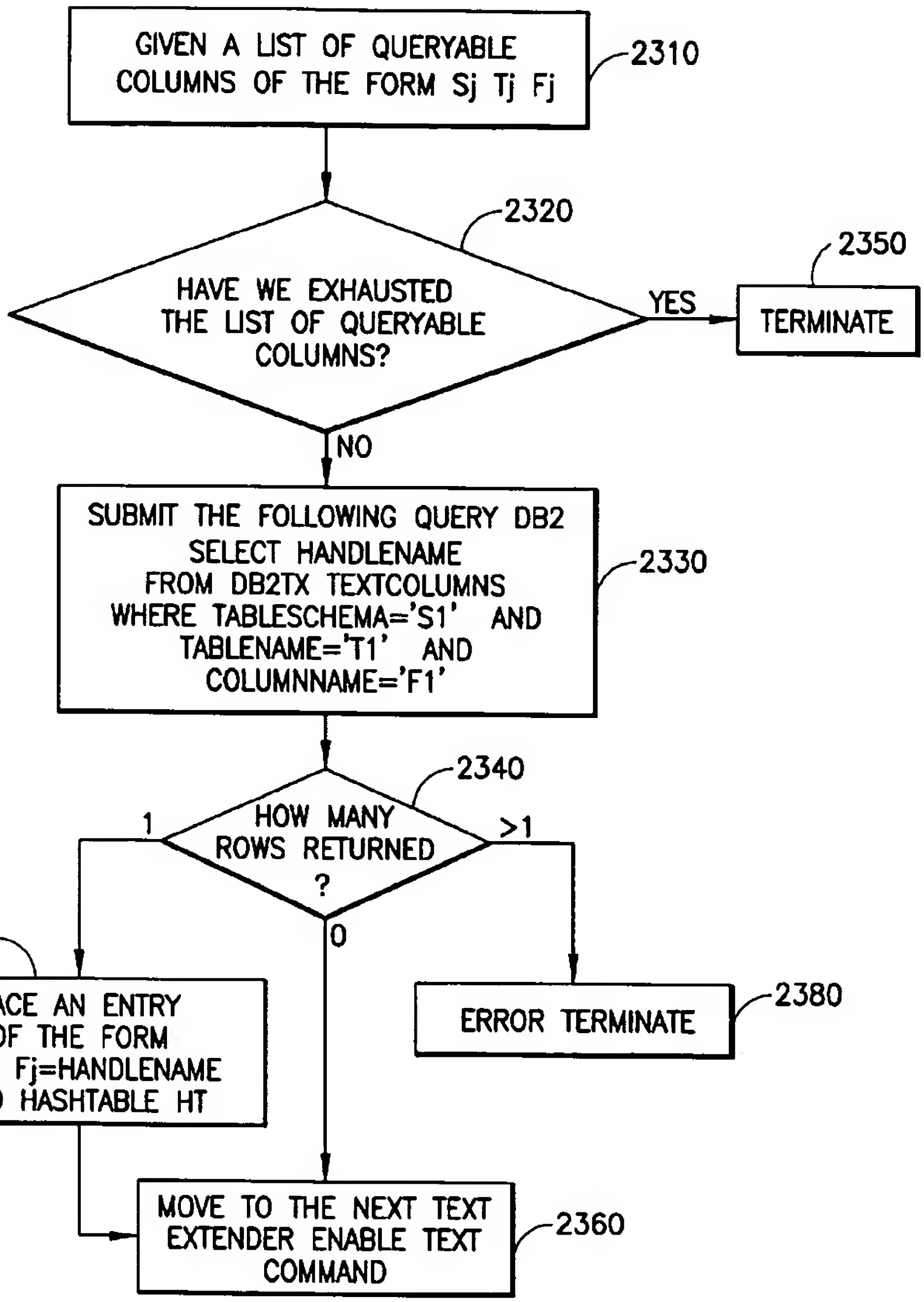

GIVEN A LIST OF QUERYABLE COLUMNS OF THE FORM Sj Tj Fj
2310
2320
HAVE WE EXHAUSTED THE LIST OF QUERYABLE COLUMNS?
YES
2350
TERMINATE
NO
SUBMIT THE FOLLOWING QUERY DB2
SELECT HANDLENAME
FROM DB2TX TEXTCOLUMNS
WHERE TABLESCHEMA='S1' AND
TABLENAME='T1' AND
COLUMNNAME='F1'
2330
2340
HOW MANY ROWS RETURNED ?
1
>1
0
2350
PLACE AN ENTRY OF THE FORM Sj Tj Fj=HANDLENAME INTO HASHTABLE HT
ERROR TERMINATE
2380
MOVE TO THE NEXT TEXT EXTENDER ENABLE TEXT COMMAND
2360

FIG.23

SYSTEM AND METHOD FOR PERFORMANCE COMPLEX HETEROGENEOUS DATABASE QUERIES USING A SINGLE SQL EXPRESSION

This application claims benefit to Provisional Application No. 60/108,754 filed Nov. 17, 1998.

FIELD OF THE INVENTION

This invention relates to computer database searching. More specifically, this invention relates to the formulation and the efficient execution of complex database queries using a single query expression against the database.

BACKGROUND OF THE INVENTION

The amount of multimedia data available in electronic format is ever increasing. The cost of loading such data into a database is quite high and it is desirable that this task does not have to be repeated when writing different applications which use such data. Furthermore it is desirable to be able to add different databases to a system without the need to rewrite the application in a major way. In general, a relational database comprises tables which contain records that have a zero-to-many relationship to records in other tables. A query is formulated against one or many tables as appropriate and upon execution returns a set of records. To get the desired user query resolved, several sub-queries queries may have to be formulated, and then the results of each of these sub-queries queries combined.

For example, assume a DB2 (IBM™) database which is populated with several tables. Each table has many records (rows) and many columns. A user can pose a query like: find all the DEALERS which have PINK CADILLACS in STOCK (referred to as parametric query). In this example, there are at least the following columns in the database: DEALERS, COLOR, MAKE, AVAILABILITY. (This is a straightforward database example). Now lets assume that with each row in the table, there is also a textual description column. Some databases like DB2 have a special method (called DB2 TextExtenders, IBM™) to search such textual columns for the occurrence of a string or a logical expression of words (e.(g. USED or NEW). A multi-search query would for instance extend the above query by adding the query condition "USED or NEW". One way to execute the query is to first execute the parametric query and store its results in an application, then execute the textual query and store its result in the application. The application then combines the results of the two sub-queries queries (e.g. parametric and textual) for a final result. The problem is that each of the sub-queries queries may return a big result set, which is expensive to transmit from the database to the application. Furthermore, combining results from the sub-queries queries is expensive.

OBJECTS OF THE INVENTION

An object of this invention is an improved database query system and method.

An object of this invention is novel object oriented query data model.

An object of this invention is to formulate a single valid query against a relational database which eliminates the use of intermediate result sets and uses the database for performance optimization while maintaining some flexibility to perform some other optimization.

An object of this invention is to formulate a single valid query as described above which returns in addition to rows from tables from the database also returns computed values in some of the result columns.

SUMMARY OF THE INVENTION

In a preferred embodiment, the present invention works in a computer system having one or more central processing units and one or more memories. The computer system has an interface to one or more databases, one or more base query objects, one or more query objects, one or more compound queries, one or more annotator objects and one of more graphical user interfaces (GUI's). The base query objects have one or more base query object methods, one or more base variables, and one or more base objects, one or more of the base query object methods being specific to the specific database and capable of querying the specific database. Each of the query objects derived from one of the base objects, and each of the query objects has a query type, one or more query object methods, one or more query object variables, and one or more query object objects. Each query object method is capable of querying a specific database to obtain a type result having the respective type. The compound query has one or more compound query methods, one or more compound query variables, and one or more compound query object objects. The operator objects, are derived from one of the base query objects that are used with the specific database. The graphical user interface (GUI) has one or more query elements with one or more operators. Each query element is one of the query types but being database independent, the query elements, operators, and conditions are user selectable. The process that, for each query element, operates on the query object with the same type as the query element to create an instance of the query object with the query element as one of the query object variables, creates one or more operator object instances from the operator objects corresponding to the operators, and operates on the compound query object to create a compound query object instance. The compound query object instance uses the instances and the operator object instances to create a query expression for the specific database. Therefore the input in the GUI is translated into a single compound query object.

There are different methods to evaluate a complex user query. In the present invention we propose a very efficient way of translating a complex user query into a single query string in a structured query language.

The query objects are created by a client process. The query objects have one or more sub-query objects and one or more execute methods that are capable of operating on their respective query object to produce one or more query expressions. All of the execute methods are capable of producing the respective query expression that is compatible with a structured query language. A compound query contains one or more boolean expressions of one or more of the query objects. The compound query has one or more compound execute methods which invoke one or more the execute methods of each of the query objects. Each of the execute methods returns their respective query expression and the compound execute method uses one or more common table expressions to combine the query expressions to form a single compound query expression that represents the boolean expression. This single expression can be executed against a database to return a result without executing any of the query expressions against the database individually.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing one non-limiting example of a preferred embodiment of the present system.

FIG. 2 is a block diagram of a novel query object architecture of the present invention.

FIG. 3 is a block diagram of a Base Query Object.

FIG. 4 is a block diagram of a Text Atom Query Object.

FIG. 5 is a block diagram of an Parametric Attribute Query Object.

FIG. 6 is a block diagram of a' Feature Atom Query Object.

FIG. 7 is a block diagram of an Operator Query Object.

FIG. 8 is a block diagram of a Parenthesis Query Object.

FIG. 9 is a block diagram of a Compound Free Text Query Object.

FIG. 10 is a block diagram of a Compound Boolean Text Query Object.

FIG. 11 is a block diagram of a Compound Parametric Query Object.

FIG. 12 is a block diagram of a Compound Feature Query Object.

FIG. 13 is a block diagram of a Boolean Compound Query Object.

FIG. 14 is a flowchart of a typical execute method which is a part of Typed Compound Query Object.

FIG. 15 is a flowchart of a typical linearize method which is a part of a Base Query Object and all Derived Query Objects.

FIGS. 15A, 15B and 15C show three representations of the same Boolean query expression, exemplifying the concepts "recursive nesting," "hierarchical tree", "parent" and "child Query Objects".

FIG. 16 is a flowchart of a typical execute method which is part of a Boolean Compound Query Object or a Compound Feature Query Object.

FIG. 17 is a block diagram of a Result Object.

FIG. 18 is a block diagram of a Common Table Expression Query Object.

FIG. 19 is a flow chart of a Compound Query Instantiation process that creates the necessary instances of Typed Elementary Query Objects, Typed Compound Query Objects, Annotator Objects and Boolean Compound Query Objects containing a query expression formulated with the previously mentioned Derived Query Objects which encapsulate a user query from input from a Graphical User Interface.

FIGS. 19A and 19B show examples of GUI query elements.

FIG. 20 is a flowchart of a high performance execute method in a Boolean Compound Query Object or a Compound Feature Query Object.

FIG. 21 is a flowchart of a high performance execute method in a Compound Free Text Query Object.

FIG. 22 is a flowchart describing the process of entering data into a hashtable as used in the high performance execute method as using in FIG. 21.

FIG. 23 is a flowchart describing an alternative process of entering data into a hashtable as used in the high performance execute method as using in FIG. 21.

DETAILED DESCRIPTION OF THE INVENTION

A preferred architecture for using the invention is described in FIGS. 1–19 below and is further described and claimed in U.S. patent application entitled A OBJECT ORIENTED QUERY MODEL AND PROCESS FOR COMPLEX HETEROGENEOUS DATABASE QUERIES to Coden et al., claiming priority to provisional patent application No. 60/108,756) which is filed on the same day as this application and is herein incorporated by reference in its entirety. The invention will be described in the description of FIGS. 20–23.

FIG. 1 is a block diagram of one preferred system **100** used in performing the process **1000** of a preferred embodiment of the present invention. This non limiting example data processing system **100** uses an IBM PC computer (trademark of IBM Corp.) running an operating system like the Microsoft Windows NT 4.0 operating system (trademark of Microsoft Corp.) and IBM Database 2 Single User Edition for Windows NT, version 2.1.2 or higher (trademark of IBM Corp.), or equivalent. The data processing system **100** includes a processor **102**, which includes a central processing unit (CPU) **104** and memory **106**. Additional memory, such as a hard disk file storage **108** and a removable media device **110** having removable media **112** may be connected to the processor **102**. Additional memory like **140** can be connected via a network and contain one or more databases **150**. The removable media device **110** may read from and, usually, writes to the removable media **112**. Examples of the removable media **112** include: a magnetic tape, a compact disk-read only (CD-ROM), write once (CD-R) or rewritable (DC_RW) memory, and any other well known readable and writable media. Memory **106, 108, 112** may have computer program code recorded therein that implements portions of the present invention in the data processing system **100**. Inputs may also be received from input devices that could include: a fax/modem **114** or network interface card **114A**, which is connected to a telephone line **132** and/or a local area or wide area network **116**. e.g. the Internet. The data processing system **100** also can include user interface hardware, such as a pointing device (e.g. a mouse) **120**, a keyboard **122**, an optical scanner **118** and a microphone **124** for allowing user input to the processor **102**. The data processing system **100** may have output devices that could include: one or more visual display devices (e.g. a monochrome or color display monitor **126**) and/or a monochrome or color display printer **128**, for rendering visual information. For instance, the Graphical User Interface (GUI) can use **126** to display the query element **134**, query operators **136** and conditions **138** which are used to specify the user query. In some alternative embodiments, the data processing system includes: an audio display device, such as a speaker **130**, for rendering audio information. A Telephone **132** may also be connected to the telephone line **116**.

Process **1900** is stored in one or more of the memories (e.g. **105, 108**) and executed by one or more of the CPUs **104**.

One problem addressed here is to be able to have any general GUI, accessing any general database with any general query. In prior art, an application had to be rewritten to accommodate a new GUI, or a new database or trying to make performance improvements. We disclose an flexible and modular architecture which creates a GUI and database independent representation of a user query which enables a GUI or database to be changed independently. Performance improvements can also be made without the need of rewriting the whole application.

FIG. 2 shows a hierarchy of objects—Base Query Objects **220**, Annotator Objects **290**, Typed Elementary Query Objects **260**, Typed Compound Query Objects **340** and Boolean Compound Query Objects **350**. This set of objects

are the core of the architecture. All the above mentioned objects are derived from a base query object (standard Object Oriented Programming meaning). Each base query object knows how to connect to a specific database, send queries to a database and receive results. Annotator Objects 290 are a convenient representation for operators and parentheses. Typed Elementary Query Objects 260 capture the basic building blocks of a query, like a text string, or a attribute, operator, value triplet (e.g., Movie Producer=Hitchcock). Typed Compound Query Objects 340 are used to express a complex query of a specific type, for instance a query of the form "SCARY SHOWER SCENE OR BIRDS FLYING" is a textual query composed of two phrases which are combined with the operator OR. Such a query would be expressed with Typed Compound Query Object 340 which would contain the query which would be expressed as the OR of two Typed Elementary Query Objects 260. A Boolean Compound Query Object 350 is used to express the complete user query which is composed of sub-queries queries of different types. The above mentioned example could be augmented to include the parametric query "DIRECTOR HITCHCOCK" and the AND operator could be used to express the fact that the user wants to find two particular Hitchcock movies ("Psycho" and "The Birds").

Process 1900 maps the information entered in the GUI into Derived Query Objects 360 which are described in detail in FIGS. 4–8. The Typed Elementary Query Objects 260 are derived from a Base Query Object 220 and contain one or more objects and methods which are able to set and write typed information from/to the GUI and map the information into a database dependent query language. Process 1900 then continues by using information either from the GUI or independently created to instantiate Typed Compound Query Objects 340 which express Boolean combinations of Typed Elementary Query Objects 260 by type and are described in more detail in FIGS. 9–12. The process 1900 then continues by using information either from the GUI or independently created to instantiate a Boolean Compound Query Object 350 which expresses the user query using Typed Compound Query Objects 340 and is described in more detail in FIG. 13. Annotator Objects 290 are used to express the Boolean combinations of objects both within the Typed Compound Query Objects 340 and the Boolean Compound Query Object 350. The Boolean Compound Query Object 350 encapsulates the user query in a GUI and database independent format.

To attach a different database the connection method in a base query object has to be changed. If the structured query language is different, only new methods expressing the change have to be added. A different GUI may entail no changes, or some changes in process 1900 which maps new graphical user interface components into Typed Elementary Query Objects 260. The core of an how an application parses a complex query and executes it would remain unchanged.

An application using the architecture described in this disclosure would be written in the following fashion. Each application has a user interface, most likely a graphical user interface (GUI). Each database which is part of the application has tables which have names and each of the tables has columns which are named in turn. The names used by the database may be not suitable for the application. An application builder can create a file which maps the database names into more user friendly names.

In the first step the GUI is mapped into Typed Elementary Query Objects 260. The names of these query objects suggest that they are the basic building blocks which can be used to express more complex user queries. For example, a Text Atom Query Object 230, encapsulates a single text string. In the next step, other aspects of the user interface are taken into account to create Typed Compound Query Objects 340, Annotator Objects 290 and a Boolean Compound Query Object 350 which ultimately describes the whole user query. The aspects of the user interface taken into account are which combinations of the basic query elements the user chose for the query. For example, besides specifying a text string, the user may specify also the resulting video for instance was aired after Aug. 14th, 1953 and was produced by either an American or Canadian company. A user interface may allow the user to specify all possible combinations of the building blocks or have default values on how they should be combined.

The Query Objects (220, 360) and their methods are some of the novel features of the disclosure. They have several characteristics in common. They provide for a user interface and database independent representation of a user query. They have methods to render them in a specific user interface, to translate them into an expression which is specific to a database and can be (either alone or in conjunction with other expressions) executed against the database. Note that the execute method is type specific. For instance, a Compound Free Text Query Object 300 has an execute method which can perform a free text query which returns ranked results. The execute method of a Compound Parametric Query Object 320 in turn returns rows which satisfy the query condition. They may contain a method to render the query into a structured query language which the user can manipulate to specify a query. They have objects to store results of a query and translate them into a user interface and database independent format which can be used for post processing if so desired. Continuing the necessary steps in an application, the query condition (e.g., the text string and the date in the above mentioned example) expressed with the above mentioned objects and captured in the Boolean Compound Query Object 350 (see description of FIG. 13 for more details) is transformed into a Boolean expression in infix notation composed of Typed Compound Query Objects 340 and Annotator Objects 290. This Boolean expression is then evaluated: each Typed Compound Query Object 340 executes the query it encapsulates and the results are then combined according to the precedence rules of the Boolean expression and the operators and parenthesis used to instantiate a result object (FIG. 17) which is again a user interface and database independent object.

The architecture is expandable to include new Query Objects at all levels (Typed Elementary Query Objects 260, Annotator Objects 290 and Typed Compound Query Objects 340) as long as they follow the same structure to include type specific execute and rendering methods. A system using this architecture can be maintained and modified at a modular level. For instance, when a new user interface is desired, some new rendering methods may have to be added to the system. A system and application using this data model can add/change a graphical user interface (GUI) without impacting the database query operation. Another example of the flexibility of the system is when adding a new different database which uses a different structured query language. In that case some of the execute methods may have to be changed but the rest of the structure and the application can remain unchanged, and there is no need to change the GUI (unless new functions are added which should be exposed to the user). Details of the database layout are hidden from the GUI and hence can be changed without impacting the application.

FIG. 2 is a block diagram of the novel Query Object architecture 200 of the present invention. The architecture

allows for one or more homogeneous databases and/or two or more heterogeneous databases 210. For each database, there is a base query object 220, which contains an object 311 encapsulating the connection to its database and an object 315 encapsulating a connection to a GUI in the system. All query objects mentioned in the description of this figure are described in more detail in subsequent figures.

There are many query objects which can be derived from a Base Query Object 220 using well known Object-Oriented techniques. Each of these Derived Query Objects 360 has a query type associated with it. Some preferred Derived Query Objects 360 shown in FIG. 2 are: the Typed Elementary Query Objects 260, the Annotator Objects 290, the Typed Compound Query Objects 340 and the Boolean Compound Query Objects 350. Some preferred Typed Elementary Query Objects are the Text Atom Query Objects 230, the Parametric Attribute Query Objects 240 and the Feature Atom Query Objects 260. Some preferred Annotator Objects are the Operator Query Objects 270 and the Parenthesis Query Object 280. Some preferred Typed Compound Query Objects are the Compound Free Text Query Object 300, the Compound Boolean Text Query Object 310, the Compound Parametric Query Object 320 and the Compound Feature Query Object 330.

The architecture is not limited to these Query Objects and can accommodate others. Each Query Object contains member objects and methods which are described in more detail in FIGS. 3–18. At least one of the methods in each of the Derived Query Objects 360 can upon execution produce a valid structured language string which in conjunction with other valid strings could be executed against the database 210 and return Results. Furthermore, each Derived Query Object 360 contains a method 390 which can render the query expression in a graphical user interface or in a user interface structured Query Language. Each Typed Compound Query Object 340 contains an object which describes a query and an object which upon execution of the query contains the results. A Boolean Compound Query Object 350 contains a query expression (a Boolean expression of Typed Compound Query Objects 340 and Annotator Objects 290), at least on linearize method which takes the query expression and transforms it into postfix notation, and at least one execute method which performs the following steps: execute the query as encapsulated in the query expression in each of the Typed Compound Query Objects 340 and then combine the results of each of these sub-queries queries according to the rules of the Operator Objects 270. The algorithms for combining are implementation specific and could also be chosen by the user.

FIG. 3 is a block diagram of a typical Base Query Object 220. A Base Query Object 220 contains objects (311, 315, 321, 325, 331, 335) methods (351, 355, 361, 365, 370, 375, 380, 385, 390, 395). Each database in the system has its own Base Query Object 220. Its main function is to know how to communicate with its associated database, in particular how to send a query and receive the results. Other important methods are: how to transform a query expression into a query using postfix notation (370), take results and transform them into a database independent format (380) and rendering methods (390) which can show data in the GUI.

All the objects and methods in a Base Query Object 220 are now described in more detail. Object 311 describes a connection to a database 210, in particular it contains all the information necessary to write execute methods 375 which can submit a query to its associated database and retrieve the results. In a preferred embodiment, the connection is to DB2 and object 311 contains methods which allow SQL strings to be executed and their results received. Object 315 describes the connection to the Graphical User Interface (GUI). In one preferred embodiment mappings from names known to the database to names preferred by the user are done in the GUI and have to be accessible to the Base Query Object 220. Object 321 contains a query expression and there are many different structures which accommodate such an expression. However, all structures represent a valid Boolean expression of Derived Query Objects 290 in an infix notation. Objects 325 are optional as an application or implementation sees fit. Object 331 describes which values the user requested as results for the query. Object 335 can hold the results of an executed query in a database and user interface independent structure. There are many suitable implementation of such an object. In one preferred embodiment, the results are table (a two dimensional array) with a separate linked list which contains the column headings and their types. The Base Query Object 220 is used to derive the Derived Query Objects 360 according to Oriented Programming rules.

Object 341 is a Compound Query Expression and there are many different structures which can accommodate such an expression. A Compound Query Expression 341 captures the same Boolean expression as the Query Expression 321 using a recursive representation which can express nesting without the use of Parenthesis Objects 280. The linearize method 371, which is described in more detail in FIG. 15, transforms a Compound Query Expression 341 into a Query Expression 321. It will be apparent in FIG. 19 how Compound Query Expressions are a useful way to represent an end user query as expressed in a GUI. A Query Expression 321 on the other hand is an useful representation for executing a user query against a database in a fast manner.

A Base Query Object 220 contains many methods. The method ADD 351 can insert Typed Elementary Query Object 260, a Annotator Object 290 or a Typed Compound Query Object 340 into the query expression 321. The method REMOVE 355 can remove any of the Query Objects from the query expression. Methods 360 are "set" and "get" methods. For each Object contained in the Base Query Object 220 there is a "set" method which can set variables and constants and a "get" method to retrieve them. Methods 365 are optional as an application or a specific implementation requires. Methods 371—the linearize methods—can transform a query expression into a Boolean expression into postfix format. There can be multiple linearize methods, at least one per structure which holds the query expression and there could be multiple ones depending on an actual implementation. Methods 375 are execute methods which execute a query against the database and retrieve results. These methods use the connection object 311 described above.

Method 380 transforms results returned from the database into a database independent format which can be used by other query objects including the GUI. In particular, method 380 knows the database specific format in which the typed results are returned from the database. In general the results can have different types like integers, floating point numbers, strings to point out a few non limiting examples. In one preferred embodiment, there are different functions to extract each of these types from the result object (FIG. 17) as returned from the database and put it into a database independent array. The types of the results (integer, floating point, string etc.) are preserved in that operation. The array has a header which for each column associates the column name, the database table it belongs to and the type. Hence enough information is retained to know from where the results came, however, the array itself (or any other equivalent representation) is database independent. As a

consequence, two such arrays could each contain results from queries executed from different databases. Some of the aspects of this methodology are covered in U.S. Pat. No. 5,873,080, entitled "Using Multiple Search Engines to Search Multimedia Data" issued to Anni R. Coden et al. on Feb. 16, 1999 which is herein incorporated by reference in its entirety. Methods **385** create strings in the structured query language which is used by the database specified in the connection **311**. Such strings (either by themselves or in conjunction with other strings) can then be executed against the database (using an execute method **375**) to produce results. In a preferred embodiment, methods **385** create SgL, strings. A common SQL statement has the following format:

SELECT<column1, column2 . . . >FROM<table1>WHERE<query condition>

The keywords SELECT, FROM and WHERE are fixed SQL keywords. The columns <column1, column2, etc> are the columns which the user specifies in a query. They can be specified in any form the GUI builder finds convenient and method **385** translates GUI specifications into column names as known by the database. In the same fashion, the user may have specified which table to search. Such specification could be directly by specifying a name or indirectly by specifying what type of query is performed. In the later case for example, the user could have specified that it is looking for an author of a book and the system knows which table is associated with such a search. The query condition is again specified by the user in different ways. For example, the user could have specified to search for authors of books which have been published in the year 1998 and whose subject is parenting. In this example the query condition specified in SQL would be SUBJECT='Parenting' and could be specified in the GUI in many different ways.

Another method **385** creates a string which translates the query condition into structured language as defined by the user interface. Methods **390**—the render method—use elements of the graphical user interface to display the query expression. Method **395** is a non limiting example of a method which can be applied to results to suit a particular application. In one preferred embodiment, method **395** is a padding method. For this method to be applied, the results contain columns which describe a start and end point of a time interval. A resulting time interval could be too small for the application to use. In this case "too" small intervals would be extended by either a fixed value or by a calculated amount as specified by the application.

The above mentioned objects and methods use standard object oriented programming technology. However, the type of objects and methods which comprise a Base Query Object **220** are novel and are necessary to implement the overall architecture of an object oriented query model. Each implementation of this architecture could very slightly.

The Typed Elementary Query Objects **260** and the Annotator Objects **290** can be considered building blocks of the Query Object Architecture and are described in FIGS. **4**–**8** in more detail. They contain the simplest forms of query expressions, like a textstring or a parametric attribute (e.g., PRODUCER='HITCHCOCK') to name two. Such query expressions can then be composed into more complex queries using the annotator objects which then are used to instantiate Typed Compound Query Objects **340**. A Typed Elementary Query Object **260** can be used to form query expressions in different Typed Compound Query Objects **340**. For instance, a query expression in a Compound Freetext Query Object **300** and in a Compound Boolean Text Query Object **310** use Text Atom Query Objects **230** in them.

FIG. **4** is a block diagram of a Text Atom Query Object **230**. Object **410** holds a basic text string which can be specified in the user interface. Such a textstring can be used to form more complex queries which are captured in Typed Compound Query Objects **340**. This Query Object is a building block, has methods for translating the string into a structured query language (e.g., adding the correct punctuation) and methods for rendering it in a GUI.

Object **420** and **430** are optional and their necessity depends on the sophistication of the Text Search Engine within the database. In one preferred embodiment. the database is DB2 and DB2 TextExtender is used to perform a text search. Within DB2 TextExtender, the language of the text string can be specified using Object **420** and DB2 TextExtender supports three types of indices (linguistic, precise and dual). Object **430** is used to specify the type of index desired. The Text Atom Query Object **230** can contain additional optional objects **440** as deemed necessary by the application or the implementation.

Methods **450** are multiple "set and get" methods for the variables, constants and objects within the Text Atom Query Object **230**. Methods **460** translate the text string into structured language strings as required by either the database **210** or the user interface structured language. Methods **480** are multiple rendering methods which use user interface elements to show the text string **410**.

FIG. **5** is a block diagram of a Parametric Attribute Query Object **240**. This query object is a building block in forming more complex expressions which are captured in Typed Compound Query Objects **340**. The information captured in a Parametric Query Object **240** is the relation as requested by a user between a particular column and a user specified value. Although a Parametric Attribute Query Object **240** does not contain explicit methods to execute a query, it contains methods on how to translate the user specification into a structured query language and methods to render them in a GUI.

Object **510** holds an attribute which is of the form <textstring><operator><value>. The operator can be any the database **210** supports and the value can be either a text string or a numeric value. The Parametric Attribute Query Object **240** can contain additional optional objects **520** as deemed necessary by the application or the implementation.

Methods **530** are multiple "set and get" methods for the variables, constants and objects within the Parametric Attribute Query Object **240**. Methods **550** translate the attribute into structured language strings as required by either the database or the user interface structured language. Methods **560** are multiple rendering methods which use user interface elements to show the attribute **510**.

FIG. **6** is a block diagram of a Feature Atom Query Object **250**. This Query Object is a building block and quite similar to the Parametric Attribute Query Object **240**. However, it has one additional feature: the user specifies a column, an operator and a value, but it does not specify the datatype of the column. For instance, a user may specify IMAGE=MOSTLY GREEN. This may translate to a particular region in a color palette, the meaning of the operand "=" being non standard and the formulation of a query varying from the standard approach.

Object **610** holds an attribute which is of the form <textstring><operator><value>. The operator can be any the database supports and is appropriate for the data type of the value which can be of any "standard" datatype like text strings and numbers, or user defined datatypes like histograms and images to give some non limiting examples.

A feature is a column in a database table whose values are strings. For example MOTION MAGNITUDE, ZOOM,

FACES are examples of features. Such features can have different values and these values can be of different type. MOTION MAGNITUDE could be described using floating numbers, ZOOM could be described using strings whose values could be IN and OUT and FACES could be described by integers like 1,2 and 3. A user searching for videos which have certain features does not want to be concerned in which format such features are described. In particular a user would for instance specify to search for videos where the MOTION MAGNITUDE=45.7.

Object **615** describes the data type of value. In one preferred embodiment the datatypes for different features as denoted in the text string in Object **610** are stored in a table in the database.

Hence the GUI designer does not need to know the type of the feature when specifying a feature atom as the information can be filled in by the application automatically. However, if the GUI needs to know the type for display purposes, it can query the system for it.

Object **620** describes which values (i.e., which columns in which tables) the user requested as results for the query. Object **625** holds the results of executing a query. FIG. **17** describes this result object in more detail.

The Feature Atom Query Object **250** can contain additional optional objects **630** as deemed necessary by the application or the implementation. Methods **640** are multiple "set and get" methods for the variables, constants and objects within the Feature Atom Query Object **250**. Methods **660** translate the feature attribute into structured language strings as required by either the database **210** or the user interface structured language. Methods **670** are multiple rendering methods which use user interface elements to show the feature attribute **610** and the feature type **620**.

FIG. **7** is a block diagram of an Operator Query Object **270**. This Query Object is a convenient implementation of operators like AND, OR, LIKE, EQUAL within this architecture. However they have the additional feature that one can use methods within an Operator Query Object **270** to overwrite the standard meaning of an operator. For instance, EQUAL may mean that two textstrings are equal if there are no differences between them or it they can be called equal when they contain the same letter independent of the punctuation and capitalization.

Object **710** is a text string describing the operator. The Operator Query Object **270** can contain additional optional objects **720** as deemed necessary by the application or the implementation.

Methods **730** are multiple "set and get" methods for the variables, constants and objects within the Operator Query Object **270**. Methods **750** translate the text string **710** into structured language strings as required by either the database **210** or the user interface structured language. Methods **760** are multiple rendering methods which use user interface elements to show the operator **710**.

FIG. **8** is a block diagram of a Parenthesis Query Object **280**. This Query Object is a convenient implementation for parenthesis which establish a precedence of evaluation within a Boolean expression.

Object **810** is a text string describing the parenthesis. The Parenthesis Query Object **280** can contain additional optional objects **820** as deemed necessary by the application or the implementation. Object **815**—identity—captures what type of parenthesis it is, e.g., left/right, round, curly and square to name a few non limiting examples.

Methods **830** are multiple set and get methods for the variables, constants and objects within the Parenthesis Query Object **280**. Methods **850** translate the text string **810** into structured language strings as required by either the database **210** or the user interface structured language. Methods **860** are multiple rendering methods which use user interface elements to show the parenthesis **810**.

The following is some pseudo code which capture the essence of Typed Elementary Query Objects **260** and Annotator Objects **290**. Each of the specific objects may contain only some of the proposed code, others some additional one.

```
public class TypedElementaryQueryObject extends Base-
  QueryObject {
  private String name;
  private String value:
  private String type;
  private OperatorObject operator,
  private LinkedList resultcolumns;
  private ResultObject results=new ResultObject( );

  public TypedElementaryQueryObject(String N, String V,
    String T, OperatorObject O) {
    name=N;
    value=V;
    type=T;
    operator=O;
  }

public ResultObject getResults( ) {
    return results;
  }

  public void setResults(ResultObject r) {
    results=r;
  }

  public void setOperator(OperatorObject op) {
    operator=op;
  }

  public OperatorObject getOperator( ) {
    return operator;
  }

  public void setresultcolumns(LinkedLtist 1) {
    resultcolumns=1;
  }

  public void setName(String s) {
    name=s;
  }

  public String getName( ) {
    return name;
  }

  public void setValue(String s) {
    value=s;
  }

  public String getValue( ) {
    return value;
  }
```

```
    public void setType(String s) {
      type=s;
    }

    public String getType( ){
      return type;
    }

    public int whoAmI( ) {
      return 18;
    }

    public String asGUIString ( ) {
      String s="("+index+": "+value+")";
    return s;
    }

    public String asSql( ) {
      String s=" ";
      String temp=value;
      if (type.startsWith("TEXT"))
        temp="'"+temp+"'";
      s="FEATURE='"+name+"'AND"+column+
        operator.asSql( )+temp;
      return s;
    }

    public ResultObject createExecute(String s) {
      results=createExecute(s, null, true);
      return results;
    }

    public ResultObject createExecute(String s, ColumnDefi-
      nition c, Boolean dir) {
      String sqlString=s+"WHERE"+asSql( );
      super.setrcolumns(rcolumns);
      results=executeStatement(sqlString, c, dir);
      return results;
    }

    public String createSQLexpression(String s) {
      String sqlString=s+"WHERE"+asSql( );
      return sqlString;
    },
}
```

FIG. 9 is a block diagram of a Compound Free Text Query Object 300. This object is used to represent a complex free text query. A free text query searches documents for the words specified in a query in a specially build index which is part of the database. Documents containing some or all of the words are returned in a rank ordered fashion, where the rank is roughly a function of the number of occurrences of the specified words in all the indexed documents in the database. (Note that different free text search engines compute the rank differently.) In one preferred embodiment, DB2 TextExtender, the free text search engine can support multiple indices (precise, linguistic and dual) as described FIG. 4 which shows the Text Atom Query Object 230. Furthermore, a user query may want to add some additional constraints which would narrow down the number of documents which should be searched for the occurrences of the words—the query condition 915 captures such constraints.

Object 910 holds the query expression, a collection of one or more Text Atom Query Objects 230. Object 915 encapsulates the query condition if the user wants to restrict the number of documents searched. For example, a query may want to find the documents which contain the word IMPEACHMENT and were written before Jan. 1st, 1998. The date condition in this example is a non limiting example of a query condition.

Object 920 denotes indices used to perform a free text search. One preferred embodiment of a free text search engine is DB2 Extenders (IBM™) which has special columns within DB2 which hold the information necessary to perform a free text search. Object 925 contains the specification of the column which is searched for the text specified in the query expression 910. Object 930 describes which values (i.e. which columns in which tables) the user requested as results for the query. Object 940 holds the results of executing a query. FIG. 17 describes this result object in more detail. Objects 950 represents optional objects which are system and implementation specific.

A Compound Free Text Query Object 300 has multiple "set and get" methods 960 for the constants, variables and objects within itself. Methods 970 are a set of rendering methods which can write for instance the query condition or the query expression and the results to the GUI. It is up to the application what information gets explicitly exposed to the user (rendered) or which values are defaulted. Some of the rendering methods can be common to several of objects and be implemented in the Base Query Object leading to an efficient implementation of the system.

Methods 965 are multiple execute methods. These methods 965 allow for a modular and flexible system and they are type specific. The execute method in the Compound Free Text Query Object 300 knows how to assemble a structured query language string which when executed returns a set of ranked documents. One of the execute methods in the Base Query Object 220 knows how to take such a structured language string and "package" it correctly so that it can be shipped to a database. As a result, the Compound Free Text Query Object 300 does not need any knowledge about the communication between the application and the database. Conversely, the Base Query Object 220 does not need any knowledge about how to assemble a free text query and deal with multiple indexes.

Methods 975 are a set of methods to create structured query language strings, either in support of the execute method or in support of the query language as implemented by the GUI.

Another important aspect of the architecture captured in this disclosure is the ability to accommodate different methods which could enhance performance without the need to rewrite the whole application. Methods 980 are preferred embodiments of such methods. The outputs of such methods are strings in a structured query language which can be combined with strings created by similar methods in other typed query objects which then create an expression in a structured query language which captures the user query and can execute it very efficiently using Common Table Expressions. Such expressions allow for temporary tables to be constructed in a database which can be used for storing intermediate results. Such tables eliminate the need to load (potentially big) intermediate results making processing more efficient.

FIG. 10 is a block diagram of a Compound Boolean Text Query Object 310. A Compound Boolean Text Query Object is quite similar to a Compound Free Text Object 300. However, a Boolean text query returns a set of documents

which satisfy a specified constraint. A document can either satisfy a certain constraint or not, hence ranking result documents does not apply to this type of queries. On the other hand, for a free text query, basically, only a set of words can be specified. In Boolean text search, the textual query condition can be quite complex: operators between the words ranging from simple and/or to 'in the same sentence as', parenthesis, synonyms etc., the complexity defined by the underlying text search engine.

Object **1010** holds the query expression, a Boolean expression of one or more text atom query objects. Object **1025** holds a Compound Query Expresssion representing the same Boolean Expression as Object **1010**. In FIG. **3** in the description of Objects **321** and **341**, these two Objects are explained in more detail. Object **1015** denotes indexes used to perform a Boolean text search. One preferred embodiment of a Boolean text search engine is DB2 Extenders (IBM™) which has special columns within DB2 which hold the information necessary to perform a Boolean text search. Object **1020** describes which values (i.e., which columns in which tables) the user requested as results for the query. Object **1030** holds the results of executing a query. FIG. **17** describes this result object in more detail. Objects **1040** represents optional objects which are system and implementation specific.

A Compound Boolean Text Query Object **310** has multiple "set and get" methods **1050** for the constants, variables and objects within itself. Methods **1060** are a set of rendering methods which can write for instance the query condition or the query expression and the results to the GUI. It is up to the application what information gets explicitly exposed to the user (rendered) or which values are defaulted. Some of the rendering methods can be common to several of objects and be implemented in the Base Query Object **220** leading to an efficient implementation of the system.

Methods **1070** are multiple execute methods. These methods allow for a modular and flexible system and they are type specific. The execute method in the Compound Boolean Free Text Query Object knows how to assemble a structured query language string which when executed returns a set of documents satisfying the specified constraint. One of the execute methods in the Base Query Object knows how to take such a structured language string and "package" it correctly so that it can be shipped to a database. As a result, the Compound Boolean Text Query Object does not need any knowledge about the communication between the application and the database. Conversely, the Base Query Object does not need any knowledge about how to assemble a Boolean text query and deal with multiple indexes.

Methods **1080** are a set of methods to create structured query language strings, either in support of the execute method or in support of the query language as implemented by the GUI.

Another important aspect of the architecture captured in this disclosure is the ability to accommodate different methods which could enhance performance without the need to rewrite the whole application. Methods **1090** are preferred embodiments of such methods. The outputs of such methods are strings in a structured query language which can be combined with strings created by similar methods in other typed query objects which then create an expression in a structured query language which captures the user query and can execute it very efficiently using Common Table Expressions. Such expressions allow for temporary tables to be constructed in a database which can be used for storing intermediate results. Such tables eliminate the need to load (potentially big) intermediate results making processing more efficient

FIG. **11** is a block diagram of a Compound Parametric Query Object **320**. A parametric query is the most basic query against a database. In general it has the form to find all documents where specified constraints hold. A basic constraint is of the form <attribute><operator><value> as described in the Parametric Attribute Query Object **240** (FIG. **5**). General constraints are Boolean expressions of parametric attributes.

Object **1110** holds the parametric query expression which constitutes the query. For example a parametric query expression would be: find the television programs whose SUBJECT is IMPEACHMENT AND whose NARRATOR is CRONKITE. The query expression is a Boolean expression of Parametric Attribute Query Objects **240**. Object **1115** holds a Compound Query Expression representing the same Boolean Expression as Object **1110**. In FIG. **3** in the description of Objects **321** and **341**, these two Objects are explained in more detail

Object **1120** describes which values (i.e., which columns in which tables) the user requested as results for the query. Object **1130** holds the results of executing a query. FIG. **17** describes this result object in more detail. Objects **1140** represents optional objects which are system and implementation specific.

A Compound Parametric Query Object **320** has multiple "set and get" methods **1150** for the constants, variables and objects within itself. Methods **1160** are a set of rendering methods which can write for instance the query expression and the results to the GUI. It is up to the application what information gets explicitly exposed to the user (rendered) or which values are defaulted. Some of the rendering methods can be common to several of objects and be implemented in the Base Query Object **220** leading to an efficient implementation of the system. Furthermore, a rendering method within the Compound Parametric Query Object **320** could use a rendering method in a Parametric Attribute Query Object **240**. For example, the rendering method within a Parametric Attribute Query Object knows how to draw a <attribute><operator><value> triplet, whereas the rendering method in the Compound Parametric Query Object **320** knows how to draw combinations and relations between such triplets. Again, each object knows how to render one thing without the need of any knowledge about the rendering of another object.

Methods **1170** are multiple execute methods. These methods allow for a modular and flexible system and they are type specific. An execute method in a Compound Parametric Query Object **320** knows how to assemble a structured query language string which when executed returns a set of documents satisfying the specified constraint. One of the execute methods in the Base Query Object **220** knows how to take such a structured language string and "package" it correctly so that it can be shipped to a database. As a result, the Compound Parametric Query Object does not need any knowledge about the communication between the application and the database. Conversely, the Base Query Object **220** does not need any knowledge about how to assemble a Boolean text query and deal with multiple indexes.

The query expression **1110** is a Boolean expression and the linearize method **370** in a Base Query Object **220** can be used to transform it into a postfix notation or any other notation which is suitable for evaluation. This is another example of the modular and streamlined architecture suggested here.

Methods **1180** are a set of methods to create structured query language strings, either in support of the execute method or in support of the query language as implemented by the GUI.

Another important aspect of the architecture captured in this disclosure is the ability to accommodate different methods which could enhance performance without the need to rewrite the whole application. Methods **1190** are preferred embodiments of such methods. The outputs of such methods are strings in a structured query language which can be combined with strings created by similar methods in other typed query objects which then create an expression in a structured query language which captures the user query and can execute it very efficiently using Common Table Expressions. Such expressions allow for temporary tables to be constructed in a database which can be used for storing intermediate results. Such tables eliminate the need to load (potentially big) intermediate results making processing more efficient.

FIG. **12** is a block diagram of a Compound Feature Query Object **330**. In many respects a Compound Feature Query Object **330** is very similar to a Compound Parametric Query Object **320**, however the differences are quite important. The query expression **1210** in a Compound Feature Query Object **330** is a Boolean expression of Feature Atom Query Objects **250** whose types are computed which implies the columns in the database to be searched. In contrast, the Parametric Attribute Query Object **240** gives a precise specification of the database search. Furthermore, in a Compound Parametric Query Object **320**, the results are rows (or parts of rows) from the database are returned, which satisfy the query expression. In a Compound Feature Query **330** the results are rows (or part of rows) and some additional computed results. The following example should clarify this statement.

Assume that there is database table F1 which has the following columns: FEATURE, START, STOP, INTVALUE, STRINGVALUE. We will focus on two entries in the feature column: MOTION MAGNITUDE and ZOOM. Motion Magnitude is specified using an integer, and hence in that row an integer value will be placed in the intvalue column. ZOOM is specified with the text string IN or OUT and hence in the rows where FEATURE is ZOOM, the appropriate values will be placed in the stringvalue column. START and STOP refer to the beginning and ending of a time interval and they are recorded as appropriate. A user query of the form: find all videos which have MOTION MAGNITUDE=10 and ZOOM=IN and return the time interval when both conditions are true require a computation of the time interval. Basically the intersection of all time intervals where MOTION MAGNITUDE=10 has to be taken with all intervals where ZOOM=IN. The results will return START and STOP columns, however the values in these columns are computed and not just retrieved from the database.

Object **1210** holds a query expression which is a Boolean expression of Feature Atom Query Objects. Object **1215** holds a Compound Query Expression representing the same Boolean Expression as Object **1210**. In FIG. **3** in the description of Objects **321** and **341**, these two Objects are explained in more detail.

Object **1220** describes which values (i.e., which columns in which tables) the user requested as results for the query. Object **1230** holds the results of executing a query. FIG. **17** describes this result object in more detail. Objects **1240** represents optional objects which are system and implementation specific.

A Compound Feature Query Object **330** has multiple set and get methods **1250** for the constants, variables and objects within itself. Methods **1260** are a set of rendering methods which can write for instance the query expression and the results to the GUI. It is up to the application what information gets explicitly exposed to the user (rendered) or which values are defaulted. Some of the rendering methods can be common to several of objects and be implemented in the Base Query Object **220** leading to an efficient implementation of the system. Furthermore, a rendering method within the Compound Feature Query Object **330** could use a rendering method in a Feature Atom Query Object **250**. For example, the rendering method within a Feature Atom Query Object **250** knows how to draw a <feature><operator><value> triplet, whereas the rendering method in the Compound Feature Query Object **330** knows how to draw combinations and relations between such triplets. Again, each object knows how to render one thing without the need of any knowledge about the rendering of another object.

Methods **1270** are multiple execute methods. These methods allow for a modular and flexible system and they are type specific. The execute method in the Compound Feature Query Object **330** knows how to assemble a structured query language string which when executed returns a set of documents satisfying the specified constraint. One of the execute methods in the Base Query Object **220** knows how to take such a structured language string and "package" it correctly so that it can be shipped to a database. As a result, the Compound Feature Query Object **330** does not need any knowledge about the communication between the application and the database. Conversely, the Base Query Object **220** does not need any knowledge about how to compute intersections and unions or other combinations of values which are returned from the database.

The query expression **1210** is a Boolean expression and the linearize method **370** in a Base Query Object **220** can be used to transform it into a postfix notation or any other notation which is suitable for evaluation. This is another example of the modular and streamlined architecture suggested here.

The execute methods in a Compound Feature Query Object **330** need to be able to evaluate a Boolean expression. There are different ways of doing so. In one preferred embodiment each Feature Atom Query is executed and the its results retained. More specific the following steps can be performed:

1) Execute the query as specified by each of the Feature Atom Query Objects **250** in the Boolean expression **1210**.

2) Obtain the query Result Objects **625** for each of the Feature Atom Query Objects **250** in the Boolean expression.

3) Substitute the query Result Objects **625** of step 2 in the Boolean expression for the Feature Atom Query Objects **250**. This results in a Boolean expression of Result Objects where the Boolean expression is identical to the one specified in the Compound Feature Query Object **330**.

4) Combine the results according to the rules of the Boolean expression and the operators involved.

FIG. **16** shows a flowchart of a typical execute method in a Compound Feature Query Object **330**.

Methods **1280** are a set of methods to create structured query language strings, either in support of the execute method or in support of the query language as implemented by the GUI.

Another important aspect of the architecture captured in this disclosure is the ability to accommodate different methods which could enhance performance without the need to rewrite the whole application. Methods **1290** are preferred embodiments of such methods. The outputs of such methods are strings in a structured query language which can be combined with strings created by similar methods in other typed query objects which then create an expression in a

structured query language which captures the user query and can execute it very efficiently using Common Table Expressions. Such expressions allow for temporary tables to be constructed in a database which can be used for storing intermediate results. Such tables eliminate the need to load (potentially big) intermediate results making processing more efficient.

The above algorithm is just one of many possible. Another embodiment for evaluating the Boolean expression is described in part in methods 1290. FIG. 20 describes this algorithm. Methods 1290 show a different way of evaluating the Boolean expression to create a string in a structured query language which is more efficient to evaluate. In one preferred embodiment, methods 1290 are common table expression methods which create instances of Common Table Expression Objects (described later in this disclosure) which in turn contain strings which describe the user feature atom query. Such expressions are used to construct a very efficient (in terms of execution time) query string.

The following is some pseudo code for a typical Typed Compound Query Object 340. Clearly, each type has different code and may contain some different methods and objects. The pseudo code shown resembles the most a Compound FreeText Query Object 300.

```
public class TypedCompoundQueryObject extends Base-
  QueryObject {
  private LinkedList resultcolumns=new LinkedList( );
  private LinkedList columnhandles;
  private LinkedList queryString;
  private String freetext;
  private ResultObject results=null;

  public TypedCompoundQueryObject(LinkedList rc,
    LinkedList ch, LinkedList q) {
    rc.reset( );
    ColumnDefinition c;
    while (rc.hasMoreElements( )) {
      c=(DB2 ColumnDefinition)rc.nextElement( );
      resultcolumns.append(c);
    }
    columnhandles=ch;
    queryString=q;
    freetext=ta.asSql( );
  }

  public int whoAmI( ) {
    return 9;
  }

  public ResultObject getResults( ) {
    return results;
  }

  public ResultObject executeQuery(ColumnDefinition
    sort, Boolean dir) {
    String columns=super.determineSelectedColumns
      (resultcolumns, 0);
    String tables=super.determineTables(resultcolumns);
    String handles=super.createCommaString
      (columnhandles);
    String sqlString="WITH TEMPTABLE("+columns+",
      RANK) AS";
    sqlString=sqlString+"(SELECT"+columns+",
      DB2TX.RANK("+handles+", '"+freetext+"')
      FROM"+tables;
    sqlString=sqlString+determineWhere(queryString)+")
      ";
    sqlString=sqlString+"SELECT * FROM TEMPT-
      ABLE WHERE RANK>0 ORDER BY RANK
      DESC";
    ColumnDefinition c=new ColumnDefinition("RANK",
      "DOUBLE", "NULL");
    resultcolumns.append(c);
    super.setrcolumns(resultcolumns);
    results=super.executeStatement(sqlString, sort, dir);
    return results;
  }

}
```

FIG. 13 is a block diagram of a Boolean Compound Query Object 350. The query expression in a Boolean Compound Query Object 350 represents the complete user query composed of Typed Compound Query Objects 340 and Annotator Objects 290. Typed Compound Query Objects 340 in turn have query expressions composed of Typed Elementary Query Objects 260 and Annotator Objects 290.

Object 1310 holds the Boolean Query Expression which constitutes the query. Object 1315 holds a second representation of the query called the Compound Query Expression. Both query expressions (1310 and 1315) express the same Boolean Expression using different representations and were shown in FIG. 3 as Objects 321 and 341. The Boolean Query Expression consists of instances of Typed Compound Query Objects 340 and Annotator Query Objects 290. For example, a Boolean expression could be of the form "(Text Query AND Feature Query) OR Parametric Query." The Compound Query Expression 1315 is described in detail in FIGS. 15 and 19.

Object 1320 holds the results of executing a query. FIG. 17 describes this result object in more detail. Objects 1330 represents optional objects which are system and implementation specific.

A Boolean Compound Query Object 350 may contain a special set of resultcolumns 1325. These results columns are used to express the following user query which is explained in two steps:

1) Determine a set of values for which a set of query condition holds.

2) To determine the final result, add the values in the specified result columns for which the user query evaluated to true.

A Boolean Compound Query Object 350 has multiple set and get methods 1340 for the constants, variables and objects within itself. Methods 1350 are a set of rendering methods which can write for instance the query expression and the results to the GUI. It is up to the application what information gets explicitly exposed to the user (rendered) or which values are defaulted. Some of the rendering methods can be common to several of objects and be implemented in the Base Query Object 220 leading to an efficient implementation of the system. Furthermore, a rendering method within the Boolean Compound Query Object 350 could use rendering methods in Typed Compound Query Objects 340.

Methods 1360 are multiple execute methods. These methods allow for a modular and flexible system. However this method is not really type specific: it knows how to traverse the query expression, invoke the execute methods in the Typed Compound Query Objects and assemble the results. One of the execute methods in the Base Query Object 220 knows how to take such a structured language string and

"package" it correctly so that it can be shipped to a database. As a result, the Boolean Compound Query Object **350** does not need any knowledge about the communication between the application and the database. Conversely, the Base Query Object **220** does not need any knowledge about how to assemble a Boolean text query and deal with multiple indexes. This method is described in more detail in FIG. **16**. A consequence of this type of a execute method is, that execute methods in the Typed Compound Query Objects could be chanced without the need of changing the execute method in the Boolean Compound Query Object **350**.

The query expression **1310** is a Boolean expression and the linearize method **370** in a Base Query Object **320** can be used to transform it into a postfix notation or any other notation which is suitable for evaluation. This is another example of the modular and streamlined architecture suggested here.

Methods **1370** are a set of methods to create structured query language strings, either in support of the execute method or in support of the query language as implemented by the GUI.

FIG. **14** is a flowchart of a typical execute method which is a part of Typed Compound Query Object **340**. Clearly, the specific execute methods are different in each type of Typed Compound Query Object **340**. It is one of the key features of this architecture, that each Query Object can create appropriate transformations from itself to either a form suitable for the GUI or a form suitable for communication with the database. Hence, the specifics of the execute method(s) in each of the Typed Compound Query Object **340** are different and there could be multiple ones, as different implementations are possible. However there is a certain commonality to these methods which is described in this FIG. **14**.

Basically, the method takes two or three inputs as appropriate: the resultcolumns **1410**, the query expression **1415** and the query condition **1420**. Each of these inputs gets transformed in an appropriate structured query language string **1425**, **1430**, **1435**, **1440**. These strings are concatenated (with the structured language specific punctuation) to form a structured language string which describes the query **1445** Q. The last step is the "packaging" of Q, as different communications protocols could be used between the application and the database. In step **1450** the communications and database dependent elements are added to Q and then submitted to the database in **1455**. In one preferred embodiment, the last three steps **1444**, **1450** and **1450** are implemented as methods in a Base Query Object **220**. Hence, in case the communications protocol needs to be changed, only the method(s) in the Base Query Object **220** have to be changed, leaving the rest of the implementation of an application unchanged.

The following is some pseudo code, specific implementation may vary.

```
public void execute( ) {
QueryList.reset( );
LinkedList component_results=new LinkedList( );
  if (QueryList.size( )==3) {
  Query o=(Query)QueryList.nextElement( );
  /* its a parenthesis */
  if (o.whoAmI( ) <6) {
  o=(Query)QueryList.nextElement( );
  combinedResults=o.executeQuery(sort, dir);
  }
  else {
  System.out.println("CompoundQuery is ill-formed");
  }
}
else {
  while (QueryList.hasMoreElements( )) {
  Query o=(Query)QueryList.nextElement( );
  /* its an operator or a parenthesis */
  if (o.whoAmI( ) <6) {
    component results.append(o);
  }
  /* its a query */
  else {
    ResultObject r=o.executeQuery(sort, dir);
    if (r==null)
      /* creates a ResultObject which identifies itself as
         being null */
      r=new ResultObject(2);
      component_results.append(r);
    }
  }
  /* component_results is a LinkedList of Annotator
     Objects and ResultObjects */
  /* mirroring QueryList with the Query Objects replaced
     by ResultObjects */
  /* convert the component_results vector from an inFix
     representation into a */
  /* postFix representation */
  LinkedList pf_results=Combine.asPostFix(component_
     results);
  /* combine the results into a single ResultObject */
  combinedResults=Combine.combine(pf_results);
  }
}
}
```

In one preferred embodiment, the result columns **1410** contain several pieces of information: for each column, the name, its type and the table it belongs to are known. Hence they can be used to deduct both the column and table information for the query.

FIG. **15** is a flowchart of a linearize method **371** in FIG. **3** for the Base Query Object **220** applicable to all Derived Query Objects **360**, or "Query Objects" for short. The method **371** transforms Compound Query Expressions (**341**, **1025**, **1115**, **1215**, and **1315**), for Typed Compound Query Objects and Boolean Compound Query Objects into Query Expressions (**321**, **910**, **1010**, **1110**, **1210**, **1310**) for these Derived Query Objects **360**. Compound Query Expressions (**341**, **1025**, **1115**, **1215**, and **1315**), are useful for the process in FIG. **19** for generating a Boolean Compound Query Object **350** from end user input to a Graphical User Interface (GUI) **127**, and Query Expressions (**321**, **910**, **1010**, **1110**, **1210**, **1310**), which are useful for the method in FIG. **20** for executing Derived Query Objects **360**, as described in the method of FIG. **20**.

The Compound Query Expressions **1315** (derived from a Compound Query Expression **341**) for the Boolean Compound Query Object **350** in FIG. **13** is itself an instance of a Boolean Compound Query Object **350**, and this instance in turn contains a Compound Query Expression **1315**, comprising in turn of some Boolean combination of Derived Query Objects **360**. We can describe this circumstance by saying that the Compound Query Expressions (**341**, **1025**, **1115**, **1215**, and **1315**), exemplify "recursion" or "recursive nesting" in that Compound Query Expressions (**341**, **1025**, **1115**, **1215**, and **1315**) contain Derived Query Objects **360**

each of which in turn contain Compound Query Expressions 341, 1025, 1115, 1215, and 1315) which contain Derived Query Objects 360 each of which contains a Compound Query Expression 341, 1025, 1115, 1215, and 1315) and so on to any level of recursive nesting. Recursion is well known algorithmic structure in general, however this application of recursion is new.

FIGS. 15A, 15B and 15C show three representations of the same Boolean query expression, exemplifying the concepts "recursive nesting," "hierarchical tree", "parent" and "child Query Objects. FIG. 15A shows an example of a Boolean query expression using a syntax of Boolean operators to connect sub-queries and parentheses to group subqueries queries. An end user could type such a query expression into a GUI query element such as a Text Entry Input Field, and well known parsing algorithms (not covered in this disclosure) could parse and interpret the text characters as query elements. FIG. 15B shows the same query expression with labels such as "1", "2", "2.1", "2.2" etc. FIG. 15C shows this same query expression as a hierarchical tree of Derived Query Objects 360, using the same labels as in FIG. 15B. Typed Compound Query Objects 340 contain "child" Derived Query Objects 360: e.g., the Compound Boolean Text Query Object 310 labeled "2.1" in FIG. 15C contains the "child" Query Object labeled "2.1.1", and Operator Object with identity "and", and Query Object "2.1.2". Such a parent/child hierarchy is well known in Object Oriented Programming, however its application here is novel.

More generally, a Derived Query Object 360, or Q can be defined as the "parent" of the Derived Query Objects contained in Compound Query Expression Objects (341, 1025, 1115, 1215, and 1315) of Q. Conversely, the Derived Query Objects 360 contained in the Compound Query Expression (341, 1025, 1115, 1215, and 1315) of Q can be called the "children" of the "parent" Query Object Q. In FIG. 15C, the Boolean Query Object 350 numbered "2" is the "parent" of the Compound Boolean Text Query Object 310 numbered "2.1", the Operator Object 270 labeled at the same level of the hierarchical tree, and the Compound Parametric Query Object 240 labeled "2.2". The latter three Query Objects in turn are the "children" of the Query Object labeled "2" in the Figure. We also define the "root" Boolean Compound Query Object 350 as that Query Object that is not contained in any other Boolean Compound Query Object 350 or any other Derived Query Object 360 within this Compound Query Expression 1315. In FIG. 15C this "root" Boolean Compound Query Object 350 is the topmost Query Object in the hierarchical tree of Query Objects, labeled with the number "1".

The preferred implementation of Compound Query Expressions Objects (341, 1025, 1115, 1215, and 1315) is a Linked List (standard program construct) of query objects, where each object can be a Typed Compound Query Object 340 or Typed Elementary Query Object 260 or an Operator Object 270. Each of the Typed Compound Query Objects 340 in turn has a Compound Query Expression (341, 1025, 1115, 1215, and 1315) comprising of Linked Lists of Derived Query Objects 360. The Compound Query Expressions (341) for Typed Elementary Query Objects 260 and Operator Objects 270 are null or "empty" in common programming terms, and we can also say these Query Objects have no "child" Query Objects. (The Compound Query Expressions (341) for Typed Elementary Query Objects 260 and Operator Objects 270 are inherited by the Base Query Object 220, in standard Object-Oriented programming terms).

We can now define the linearize method 371 with flowchart in FIG. 15 as a method that applies to all Derived Query Objects 360, including Operator Objects 270, beginning with the "root" Boolean Compound Query Object 350 or Q. The method does two things:

(1) The method 371 transforms the Compound Query Expression 1315 of this "root" Boolean Compound Query Object 350 or Q into a Query Expression 1310. The Query Expression 1310 for Q will comprise of Typed Compound Query Objects 340, Operator Objects 350 connecting pairs of Typed Compound Query Objects 340, and Parenthesis Objects 280 that may group one or more Typed Compound Query Objects 340. In effect, the method 371 turns the "hierarchical tree" exemplified in FIG. 15C into a linear expression exemplified in FIG. 15A.

(2) The method 371 is applied to the Typed Compound Query Objects 340 in the Compound Query Expression (341, 1025, 1115, 1215, and 1315) for Q and transforms the Compound Query Expression (341, 1025, 1115, 1215, and 1315) in each of these "child" Typed Compound Query Objects 340 into a Query Expression 1315 that in turn can comprise of combinations of "child" Typed Compound Query Objects 340, and/or Typed Elementary Query Objects 260, Operator Objects 270 connecting pairs of Typed Compound Query Objects 340 and/or Typed Elementary Query Objects 260, and Parenthesis Objects 280 that may group one or more Typed Compound 340 or Typed Elementary Query Objects 260, such that resulting Query Expression 1315 represents a well-formed and executable Boolean Compound Query Expression 350.

In contrast to the recursive Compound Query Expressions (341, 1025, 1115, 1215, and 1315), the Query Expression 1315 is a non-recursive structure, where the order of Derived Query Objects 360 and Annotator Objects 290 is determined by the linearize method to match the order of Derived Query Objects 360 and Annotator Objects 290 in the Compound Query Expressions (341, 1025, 1115, 1215, and 1315).

Referring again to FIG. 15, any Query Object Q, Step 1520 determines if the Compound Query Expression (341, 1025, 1115, 1215, and 1315) for Q is empty. The Compound Query Expression (341) would be empty for Typed Elementary Query Objects 260 and Operator Objects 270 because these Query Objects are elementary, and have no "child" Query Objects, only values (e.g., text terms for a Text Atom Query Object 230, or an identity "left" or "right" for a Parenthesis Query Object 280).

If the Compound Query Expression (341, 1025, 1115, 1215, and 1315) is not empty the Steps beginning with 1530 are executed. Step 1530 determines whether there are any Query Objects left. Step 1544 determines whether a Derived Query Object 260, or q in the Compound Query Expression is Typed Elementary Query Object 260 or an Operator Object 270. If "yes" to either case, then Step 1546 adds q to the Query Expression (341, 1025, 1115, 1215, and 1315) for Q. If the Query Object q is a Typed Compound Query Object 340, then the Steps beginning with 1552 are executed: Step 1552 sets the parent value of q' to the Query Object Q using set methods 361 in FIG. 3 for the Base Query Object 220. (This information will be used in Step 1562 below.) Step 1555 applies the linearize method 371 in FIG. 3 to each Derived Query Object 360 q' in the Compound Query Expression (341, 1025, 1115, 1215, and 1315) which results from applying the linearize method to the Derived Query Object 360, or q in the Compound Query Expression (341, 1025, 1115, 1215, and 1315) for the "parent" Derived Query Object 360 Q. Step 1558 adds the Query Object q' to the Query Expression 1315 for Q: using the "parent" and

"child" terminology above we can say that the "parent" Query Object Q adds to its Query Expression 1315 all the "children" in each of it's "child" Query Objects q.

When the steps beginning with 1552 are completed for all the "child" Derived Query Objects 360 q in the Compound Query Expression (341, 1025, 1115, 1215, and 1315) for the "parent" Q, the steps beginning with Step 1565 determine the content of the Query Expression 1315 for the "parent" Derived Query Object 360 Q. Step 1565 determines whether the "parent" Q is a Boolean Compound Query Object 350. If "yes" Step 1570 inserts a Parenthesis Object 280 with the identity 815 "left" into the Query Expression 1315, and Step 1574 adds a Parenthesis Object 280 with the identity 815 "right" into the Query Expression 1315, and Step 1580 exits the linearize method.

If Step 1565 determines whether the "parent" Query Object Q is a Boolean Compound Query Object 350, and the Step 1562 determines whether the "parent" of the "parent" Query Object Q is itself a Boolean Compound Query Object 350, using the get methods 361 in FIG. 3 for the Base Query Object 220. If yes, then Step 1528 sets the Query Expression 1315 for the Query Object Q to Q itself, rather than the "child" Derived Query Objects 360 of Q from Steps beginning in 1530. Step 1570 inserts a Parenthesis Object 280 with the identity "left" into the Query Expression 1315, and Step 1574 adds a Parenthesis Object 280 with the identity "right" into the Query Expression 1315, and Step 1580 exits the linearize method.

The Steps 1562 and 1528 ensure that the Query Expression 1315 for the "root" Boolean Compound Query Object 350, defined as the Boolean Compound Query Object 350 with no parent itself, only contains Typed Compound Query Objects 340, Annotator Objects 290, and no Typed Elementary Query Objects 260.

If Step 1562 determines that the "parent" Query Object Q is not itself a Boolean Compound Query Object 350, then the Query Expression 1315 for Q is used as derived from the Steps beginning 1530 through 1558, and Step 1570 inserts a Parenthesis Object 280 with the identity 815 "left" into the Query Expression 1315, and Step 1574 adds a Parenthesis Object 280 with the identity 815 "right" into the Query Expression 1315, and Step 1580 exits the linearize method 371.

These Steps ensure that the Compound Query Expressions (341, 1025, 1115, 1215, and 1315) for all the Typed Compound Query Objects 340 (where the latter objects are contained in the Compound Query Expressions (341, 1025, 1115, 1215, and 1315) for the "root" Boolean Compound Query Object (350) contain all the "child" Derived Query Objects 360 developed as a result of the Steps beginning 1530.

When Step 1520 is applied to any Operator Query Object 270, or to a Typed Elementary Query Object 260, the Compound Query Expression for that Query Object is empty, in which case Step 1525 adds the Query Object itself to its Query Expression 1315, and Step 1580 exits the linearize method 371.

FIG. 16 is a flowchart of a typical execute method which is part of a Boolean Compound Query Object 350 or a Compound Feature Query Object 330. It applies to any Query Object where the query expression is a Boolean expression of query objects, each of which having its own execute method.

The input to an execute method 1360 of a Boolean Compound Query Object 350 is a Boolean Expression comprising of Typed Compound Query Objects 340 and Annotator Objects 290. The process of arriving at such a Boolean Expression is shown in FIG. 19.

In one preferred embodiment, each Typed Compound Query Object 340 is executed separately and its Result Object (FIG. 17) substituted in the Boolean Expression for the Typed Compound Query Object 340, resulting in a Boolean Expression of Result Objects. These Result Objects are then combined according to the rules of the Boolean Expression. There are different ways of implementing the above described steps and one preferred embodiment is now outlined.

The input 1605 to an execute method is a Boolean Expression of Typed Compound Query Objects 340 and Annotator Objects 290. The next step 1610 tests whether there are any components left in the expression. In the affirmative case the next object in the Boolean Expression is checked 1615 to determine whether it is an Annotator Object 290. An Annotator Object is pushed on the stack S in 1620. A Typed Compound Query Object 340 is evaluated in 1625 by calling its execute method and the resulting Result Object (FIG. 17) is pushed on the stack S. Then the Boolean Expression 1605 is tested again to see whether there are any objects left to be evaluated. When there are no more objects left, the content of the stack S—which form a Boolean expression in prefix format are converted to a Boolean Expression PF in postfix format in box 1630. This step is done with one of many well known algorithms. The result of this step is shown in box 1635—PF—the Boolean expression in postfix format.

The execute method continues by examining each object in the Boolean Expression PF in turn. In case there are objects left in PF, which is checked in 1638, the next object is checked whether it is a result object (FIG. 17) in 1640. Result Objects are pushed onto a stack T 1645. In case the next object is an operator object, some computation is performed in 1650: The last two objects are popped from the stack T 1645, and the operator object is applied between these two just popped result object (FIG. 17). Applying the operator then results in a new result object which is pushed onto stack T. When no more objects are encountered in 1635, there is only one object remaining on the stack T, which is popped from the stack and returned as the result of the execute method in 1655.

FIG. 17 is a block diagram of a Result Object. One key feature of this Query Object architecture is that all appropriate Query Objects have the same type of result object. The result object is database and GUI independent and has a rich set of access functions to it. It also contains methods to transform into an application specific representation. For instance, it could be advantageous to change the names of the columns or add a column to make all the result objects be of the form which is necessary for the execute method in a Boolean Compound Query as described in FIG. 16.

Object 1710 holds the result column headings. Each heading contains the name of the column, the table it belongs to and its type. All the headings can then be arranged either in an array or a linked list or another ordered structure. The ResultRows 1715 are a two dimensional array containing the values of the results. There are a multitude of implementations for such an array and depend on the language the application is written. Objects 1720 are optional and implementation specific.

There are set and get methods 1725 for all the contained objects, variables and constants in the Result Object. Method 1730 is a transform method which is application specific. This method can for instance change the names in the columns, change values if appropriate (e.g., change all negative values to zero) or any other application specific transformation. Invoking method 1735—NumberOfResults

returns the number of rows in a particular Result Object. Another quite useful method is GetColumnValues **1740** which returns all the values for a specific column.

The Normalize method **1745** is invoked mainly to accommodate the execute method **1360** in a Boolean Compound Query Object **350** described in FIG. **13**. All the result objects which are input to such an execute method are of the same structure—they have the same number of columns which all have the same headings. To achieve that, one or more columns and their values may have to be added to a result object which is done in the Normalize method **1745**. There can be some optional methods **1750**.

The query object architecture is a flexible and expandable one. At times, it is appropriate to introduce new query objects due to the type of data and/or application at hand. Introducing new query objects allows for instance for the Compound Query Instantiation process to stay unchanged or for some execute methods to be reused. The Common Table Expression Query Object as described in FIG. **18** is a query object introduced to facilitate query expression evaluation. It enables the algorithm for traversing a Boolean expression and taking into account precedence of operators to stay unchanged and at the same time create a structured language string which is much faster to evaluate.

FIG. **18** is a block diagram of a Common Table Expression Query Object. This object is a good example of the flexibility and expandability of our architecture. Two basic concepts are: a Boolean expression which represents a user query is composed of Query Objects. In turn, each Query Objects has a method to translate the query it represents into a database specific query language. The Common Table Expression Query Object is a Query Object which contains a specific translation of a query or sub-query into SQL which is optimized for performance.

The Common Table Expression Query Object contains at least two objects: the name object **1810** and the SqlString object **1820**. The name is generated using method **1860**. One preferred embodiment of the name generation is to use a fixed textstring and append a number to it. The application keeps track of the numbers used so far. The SqlString in general is created during an execute method of a different object which uses a Common Table Expression Object to store intermediate results.

Methods **1840** are set/get methods for the objects, variables and constants used in the Common Table Expression Object.

Objects **1830** are optional objects which are implementation and application specific as are the optional methods **1860**.

The following examples are written in SQL and show examples of strings as they may appear in Object **1820**.

1) T1 (VIDEO, DATE) AS (SELECT VIDEO, DATE FROM TABLE1 WHERE TOPIC='HAPPINESS' AND LOCATION='NEW YORK')

The above expression augmented with the keyword WITH creates a temporary table T1 which has two columns VIDEO and DATE. These two columns have values taken from TABLE1 which contains the columns TOPIC and LOCATION and satisfy the two constraints TOPIC='HAPPINESS' and LOCATION='NEW YORK'

2) T2 (VIDEO, DATE) AS (SELECT VIDEO, DATE FROM TABLE2 WHERE ANCHOR='DAN RATHER')

The above expression augmented with the keyword WITH creates a temporary table T2 which has two columns VIDEO and DATE. These two columns have values taken from TABLE2 which contains the columns ANCHOR and which satisfy the constraint ANCHOR='DAN RATHER'.

3) T3 (VIDEO, DATE) AS (SELECT VIDEO, DATE FROM T1, T2)

The above expression creates a temporary table T3 which contains data which is either in T1 or T2 (i.e., logical OR)—the common table expressions constructed in 1) and 2).

4) T4 (VIDEO, DATE) AS (SELECT VIDEO, DATE FROM TABLE3 WHERE RELEASE<1995 UNION ALL SELECT VIDEO, DATE FROM T2

The above expression creates a temporary table T4 which contains data which is either in TABLE3 and satisfies the constraint RELEASE<1995 or in T2 (i.e., logical AND)

The above examples are quite simple and in some cases may be written more simply. However their importance will be apparent in the discussion of FIG. **20** where an execute method of a Boolean Compound Query Object is discussed.

FIG. **19** is a flow chart of a Compound Query Instantiation process that transforms inputs like text strings originating as elements of a Graphical User Interface (GUI) into an instance of a Compound Query Expression **1315** for a Boolean Compound Query Object **350**. This Compound Query Expression (**341, 1025, 1115, 1215**, and **1315**) in turn contains one instance of a "root" Boolean Compound Query Object **350**, and this Query Object contains a Compound Query Expression **1315**, which contains a collection of Derived Query Objects **360** comprising of Typed Elementary Query Objects **260**, Typed Compound Query Objects **340**, and Operator Query Objects **270** in combinations that represent a well-formed Query Expression **1310** when the method of FIG. **15** is applied to the "root" Boolean Compound Query Object **350**.

Typed Compound Query Objects **340** contained in Compound Query Expression (**341, 1025, 1115, 1215**, and **1315**) can be termed for convenience "child" Query Objects of the Query Object whose Compound Query Expression (**341, 1025, 1115, 1215**, and **1315**) contains them. For convenience, we can also define the Query Object Q whose Compound Query Expression contains these "child" Query Objects, as the "parent" of those Query Objects contained in the Compound Query Expression (**341, 1025, 1115, 1215**, and **1315**) of Q. The definitions are the same as those defined for the linearize process of FIG. **15**, and FIG. **15C** shows an example of a Compound Boolean Query Object **350** with "child" Query Objects displayed in a hierarchical tree, where the "child" Query Objects are in turn "parents" of lower level "child" Query Objects.

The Compound Query Instantiation process in FIG. **19** is initiated by some kind of Graphical User Interface (GUI) event, e.g., a preferred implementation corresponds to the end user pressing a "Search" button in the GUI. The process comprises writing code that includes the following the steps (1) through (4), embodied in program code:

(1) Program code is written in such a way that each GUI query element and program code unit can be associated with one Derived Query Object **360** in the Boolean Compound Query Object **350** expressed by the GUI query elements taken as a whole.

(2) Program code is written in such a way that each GUI query element can be evaluated as a "valid" query element that expresses an end user's intention to use that GUI query element to represent a particular type of Query Object.

(3) Program code is written in such a way that it produces valid Compound Query Expressions (**341, 1025, 1115, 1215**, and **1315**), adding "child" Query Objects to "parent" Typed Compound Query Objects **340** in a way that expresses a well-formed Boolean query expression, including Operator Query Objects **270** connecting pairs of Query Objects.

(4) Program code is written in such a way that the GUI query elements and program code units which use and operate on these GUI query elements, resulting from these process steps (1), (2), (3) and (4) taken in their totality, and executed as a program (with end user input to the GUI query elements) will instantiate a Boolean Compound Query Object **350** that comprises of Boolean combinations of Derived Query Objects **360** including Typed Elementary Query Objects **260**, Typed Compound Query Objects **340**, and Operator Query Objects **270** connecting pairs of these Query Objects. The process of instantiation is described by the flowchart in FIG. **19**.

In assumption (1) a GUI query element and/or program code unit can be associated specifically with an Typed Elementary Query Object **260** (e.g., a Text Atom Query Object **230**, an Parametric Attribute Query Object **240**, or a Feature Atom Query Object **250**), an Operator Query Object **270**, or a Typed Compound Query Object **340** (e.g., a Compound Boolean Text Query Object **310**, a Compound Parametric Query Object **220**, or a Compound Feature Query Object **330**). GUI query elements and program code units can relate to Query Objects of any type.

FIGS. **19A** and **19B** show examples of GUI query elements, with user input, and the descriptors with arrows pointing to the GUI query elements label these elements in conjunction with pseudocode described below. FIG. **19A** shows a form with GUI query elements representing text query criteria, parametric criteria, and feature criteria (see labels in figure). Select GUI query elements are also labeled with program names used in the pseudo-code below: e.g., the "textAtomInput1" GUI query element is a standard GUI text entry field into which a user has typed "Bill Clinton" as a text query term. These text terms "Bill" and "Clinton" are extracted by program code, and used to set the value of a single Text Atom Query Object **230** ("Bill Clinton").

There may be multiple of these GUI query elements expressing Text Atom Query Objects **230** of a Boolean Text Query Object **31**, as FIG. **19A** shows. Additional GUI query elements allow end users to specify the value of Operator Query Objects **270** expressing Boolean operators connecting these Text Atom Query Objects **230**. Hence GUI query elements can express groupings that correspond to various types of Typed Compound Query Objects **340**.

Alternatively, FIG. **19B** shows a single GUI text entry field may contains a complex Boolean query expression multiple component query criteria connected by Boolean operators, in which case this single GUI query element actually resolves into a Boolean Compound Query Object **350** of any complexity as implied in the end user's typed query expression. FIG. **19B** in particular shows a GUI query element into which an end user types a Boolean query expression which is parsed by program code (this parsing process is not covered by this disclosure) to create the Boolean Compound Query Object **350** that was also shown in FIG. **15A**.

Finally, there may not be a GUI query element for a Query Object, but a program code unit that creates a Query Object by programmer stipulation: e.g., there may be no explicit GUI query element for specifying a Boolean operator, but there is a program code unit that creates an Operator Query Object **270** with a stipulated value (also called a "default" value in programming terms). These methods are illustrated with pseudo-code below.

In assumption (2), a "valid" GUI query element is simply one that an end user has acted on and in so doing has specified a value (e.g., typed in text terms representing keywords for a text query), and thereby expressed the intention to include the Query Object associated with GUI query element an a component of an overall Boolean Compound Query Object **350**. A GUI query element may also be valid by virtue of program logic that relates two or more GUI query elements. For example, a user may specify the value of an GUI query element representing an Operator Query Object **270**, but this action only makes the query element a valid representation for the Operator Query Object **270** if the user also specifies (makes "valid") values for GUI query elements that are associated with Query Objects which would be connected by the Operator Object **270** in question. Standard programming practices can readily implement such program relations among GUI query elements.

In assumption (3), program logic is written such that "valid" GUI query elements are used to set values of Derived Query Objects **360** in FIG. **2**, using set methods **361** in the Base Query Object **220**, and program logic uses add methods **351** in the Base Query Object **220**, to create combinations of Derived Query Objects **360** connected by Operator Objects, and contained in the Compound Query Expressions (**341**, **1025**, **1115**, **1215**, and **1315**) of Typed Compound Query Objects **340**, which in turn may be connected by Operator Query Objects **270**, and which make up the content of a "root" Boolean Compound Query Object **350**.

The GUI query elements can be defined and/or how program code can be written in any general way to satisfy assumptions (1), (2), (3), or (4). However, the GUI allows end users to specify a valid Boolean Compound Query Object **350** composed of Derived Query Objects **360** connected by Operator Query Objects **270** and must satisfy the five assumptions in the prior paragraph. The programming process fulfills the assumptions (1) through (4), and results in the generation of a "root" Boolean Compound Query Object **350**, and all the Derived Query Objects **360** contained in its Compound Query Expression (**341**, **1025**, **1115**, **1215**, and **1315**).

Once GUI query elements and program code are written to satisfy these assumptions (1)-(5), the process in FIG. **19** will "instantiate" a Boolean Compound Query Object **350**, and all the Derived Query Objects **360** that are contained in its Compound Query Expression (**341**, **1025**, **1115**, **1215**, and **1315**), as intended by the end user.

In the preferred implementation, standard programming methods are used to associate GUI query elements and program code units with instances of Derived Query Objects **360**. The end user expresses his or her intentions by interacting with the GUI query elements to specify values of the Query Objects associated with the GUI query elements. Instantiating for Typed Elementary Query Objects **260** means GUI query element values are used to set Query Object values using set methods **361** in the Base Query Object **220**. Instantiation for Typed Compound Query Objects **340** means that "child" Derived Query Objects **360** are added to the Compound Query Expressions (**341**, **1025**, **1115**, **1215**, and **1315**) for these Typed Compound Query Objects **360**, using add methods **351** in the Base Query Object **220**. The result Boolean Compound Query Object **350** provides the Compound Query Expression (**341**, **1025**, **1115**, **1215**, and **1315**) needed for the other methods and processes covered by this disclosure. The following pseudo-code illustrates this process of instantiation and adding of Derived Query Objects **360** to Typed Compound Query Objects **340**. The pseudo-code immediately below provides an example of how GUI query elements are related to instantiation of Derived Query Objects **360**:

```
1) textAtomInput1=new TextEntryField( );
2) textOperator1=new TextEntryField( );
3) textAtomInput2=new TextEntryField( );
4) textOperator2=new TextEntryField( );
5) textAtomInput3=new TextEntryField( );
6)
7) textOperator3=new TextEntryField( );
8)
9) textAtomInput4=new TextEntryField( );
10) textOperator4=new TextEntryField( );
11) textAtomInput5=new TextEntryField( );
12) textOperator5=new TextEntryField( );
13) textAtomInput6=new TextEntryField( );
14)
15) compoundOperator1=new TextEntryField( )
16)
17) attributeAtomNameInput1=new TextEntryField( );
18) attributeOperator1=new TextEntryField( );
19) attributeAtomValueInput1=new TextEntryField( );
20)
21) attributeOperator2=new TextEntryField( );
22)
23) attributeAtomNameInput2=new TextEntryField( );
24) attributeOperator3=new TextEntryField( );
25) attributeAtomValueInput2=new TextFntryField( );
26)
27) compoundOperator2=new TextEntryField( );
28)
29) featureAtomNameInput1=new TextEntryField( );
30) featureOperator1=new TextEntryField( )
31) featureAtomValueInput1=new TextEntryField( );
32)
33) featureOperator2=new TextEntryField( )
34)
35) featureAtomNameInput2=new TextEntryField( );
36) featureOperator3=new TextEntryField( )
37) featureAtomValueInput2=new TextEntryField( );
38)
39) if (textAtomInput1.isValid( ) & textAtomInput2.isValid(
  )) {
40) textAtom1=new TextAtom(textAtomInput1.getTerms(
  ));
41) textAtom2=new TextAtom(textAtomInput2.getTerms(
  ));
42) textOperator1=new Operator(textOperator1.getIdentity(
  ));
43) booleanTextCompound1=new BooleanTextCompound(
  );
44) booleanTextCompound1.add(textAtom1);
45) booleanTextCompound1.add(textOperator1);
46) booleanTextCompound1.add(textAtom2);
47) if (textAtomInput3.isValid( )) {
48) textAtom3=new TextAtom(textAtomInput3.getTerms(
  ));
49) textOperator3=new Operator(textOperator3.getIdentity(
  ));
50) booleanTextCompound1.add(textOperator2);
51) booleanTextCompound1.add(textAtom3);
52) }
53) }
54) if (textAtomInput4.isValid( ) & textAtomInput5.isValid(
  )) {
55) textAtom4=new TextAtom(textAtomInput1.getTerms(
  ));
56) textAtom5=new TextAtom(textAtomInput2.getTerms(
  ));
57) textOperator3=new Operator(textOperator1.getIdentity(
  ));
58) booleanTextCompound2=new BooleanTextCompound(
  );
59) booleanTextCompound2.add(textAtom4);
60) booleanTextCompound2.add(textOperator3);
61) booleanTextCompound2.add(textAtom5);
62) if (textAtomInput6.isValid( )) {
63) textAtom6=new TextAtom(textAtomInput6.getTerms(
  ));
64) textOperator4=new Operator(textOperator3.getIdentity(
  ));
65) booleanTextCompound1.add(textOperator4);
66) booleanTextCompound1.add(textAtom6);
67) }
68) }
69) if (booleanTextCompound1.hasContents( ) &
  booleanTextCompound2.hasContents( )) {
70) booleanTextCompound3=new BooleanTextCompound(
  );
71) booleanCompound=new BooleanCompound( );
72) booleanCompound.add(booleanTextCompound3);
73) booleanCompound.add(new Operator("AND"));
74) booleanCompound.add(parametricCompound1);
75) }
76)
77) etc. for Parametric attributes, Features, etc.
```

In the pseudo-code example, a set of GUI query elements are defined in lines 1–38 and given names identifying the type of Query Object created from the query element. This is standard programming practice. These lines of code can also be viewed in relation to the GUI example in FIG. 19A: e.g., the GUI query element labeled "textAtomInput1" in line 1 of the pseudo-code above is shown in FIG. 19A. Lines 1, 3 and 5 of the pseudo-code corresponds to the GUI query input elements in FIG. 19A containing the name "Bill Clinton", "visit" and "China". Note the not all the GUI query elements listed in the pseudo-code are labeled in FIG. 19A, but just a few to suggest the correspondence. The lines 39–77 define blocks of code that test if the GUI query elements related to the Text Atom Query Objects **230** are "valid" and creates Derived Query Objects **360**, including Compound Boolean Text Query Objects **310**. "Valid" means the user has typed terms in the input fields, e.g., "Bill Clinton", vs leaving the text entry field blank. Lines 39–53 for example test if three text entry fields named "textAtomInput1" and "textAtomInput2" and textAtomInput3 are "valid." In FIG. 19A, this means the end user has entered text terms "Bill Clinton", "visit" and "China". The end user may or may not have specified the "&" operators connected these terms. If the two input fields are "valid" than the block of code is executed: the code in lines 40–42 create two Text Atom Query Objects **230**, and an Operator Object **270**, and the lines 43–46 create a Compound Boolean Text Query Object **310**, and adds the Text Atom Query Objects **230** and Operator Object **270** to the this Query Object, using the "add" method **351** in the Base Query Object **220**. The "add" method adds the "child" Query Objects to the Compound Query Expression **1025** of the Compound Boolean Text Query Object.

The lines of code 69–75 create another Compound Boolean Text Query Object **310**. If the Compound Boolean Text Query Objects resulting from lines of code 39–53 and 54–68 have contents, the lines 69–75 create yet a third Compound Boolean Text Query Object **310**, and adds the Compound Boolean Text Query Objects **310** from lines of code 39–53 and 54–68 as "child" Query Objects, connected by an Operator Object. Additional lines of code of similar form could be written for Parametric Attribute Query Objects **240**

and Feature Atom Query Objects **250**, and their corresponding Compound Parametric Query Objects **320** and Compound Feature Query Objects **230**.

The pseudo-code illustrates all the steps (1)–(4) above: how GUI query elements are used to instantiate Derived Query Objects **360**, how Operator Objects **270** can become "valid" by virtue of the "validity" of other Query Objects, and can have "default" values stipulated by program code, and not necessarily end user input, and how one Derived Query Object **270** can be added to a Typed Compound Query Object **340**.

We define a special case of the Boolean Compound Query Object **350** resulting from program execution, called a "GUI-Complete" Boolean Compound Query Object **350**: The "GUI-Complete" Boolean Compound Query Object **350** is the Query Object that would result if an end user interacted with the GUI to make every GUI query element "valid". It is therefore the most complete theoretically possible Boolean Compound Query Object **350** that could result from executing the program code according to the steps (1), (2) and (3).

We can now preview the process in FIG. **19** as one that "instantiates" an actual Boolean Compound Query **350**, starting from this ideal "GUI-Complete" Boolean Compound Query Object **350**. The process instantiates a set of Derived Query Objects **360** that correspond to "valid" GUI query elements, and/or program code that combines Query Objects into Typed Compound Query Objects **340**. All these Query Objects are ultimately contained in a Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) of a "parent" Boolean Compound Query Object **350**. Another way to describe this is to say that the "GUI-complete" Boolean Compound Query Object **350** is used as a template or skeleton, to guide the process of Compound Query Instantiation depicted in FIG. **19**, in the sense that process depicted in FIG. **19** examines each Query Object in the GUI-Complete Boolean Compound Query Object **351**, and if the GUI query element associated with it is "valid", a new Query Object Q^{Result} of the same type is created, its values set using set methods **361** for the Base Query Object **220**, and using the data contained in the "valid" GUI query element, and Q^{Result} is added to the Compound Query Expression **341, 1025, 1115, 1215,** and **1315**) of the "parent" Query Object for Q^{Result} using add methods **351** for the Base Query Object **220**. The result of the process in FIG. **19** therefore is a new Boolean Query Object **350** built out of Query Objects selected from, and instantiated (values set) from the corresponding Query Objects of the GUI-Complete Boolean Compound Query Object **3500**. The order and grouping of "child" Query Objects in this final resulting Boolean Compound Query Object **350** is strictly parallel to order and grouping of the GUI-Complete Boolean Compound Query Object **3500**, except for Query Objects that do appear in the resulting Boolean Compound Query Object **350** because the GUI query elements associated with them were not "valid".

The process applied to any given Query Object $Q^{GUI\text{-}Complete}$ at any level in this recursive nested structure begins with Step **1905** which creates a new but uninstantiated Query Object Q^{result} of exactly the same type. Uninstantiated means that if Q^{result} is a Typed Elementary Query Object **260** it has no value (get method of **351** returns "null" or "empty" in common programming terms), or if Q^{result} is a Typed Compound Query Object **340** its Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) is empty (has no "child" Query Objects). Step **1910** determines whether the Query Object $Q^{GUI\text{-}Complete}$ is a Typed Elementary Query Object **260** or a Typed Compound Query Object **340**. If the Query Object $Q^{GUI\text{-}Complete}$ is either an Typed Elementary Query Object **260** or an Operator Query Object **270**, Step **1962** determines whether the Query Object has a "valid" GUI query element associated with it. If the GUI Query Element is "valid" (i.e., an end user has specified a value for it), Step **1966** sets the value of Q^{result} using set methods **361** in the Base Query Object **220**, and Step **1990** returns the Q^{result}. For example a GUI query element such as a text entry field would be "valid" if an end user typed text keywords such as "Bill Clinton", and the typed text "Bill Clinton" would be used to set the value of a Text Atom Query Object **230**. Conversely, if the GUI query element is not "valid", the Query Object Q^{result} is still returned in Step **1990** but it is has no value or is "empty".

Returning to Step **1910**, if Step **1910** determines that the Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) of the Query Object $Q^{GUI\text{-}Complete}$ is a Typed Compound Query Object **340**, Step **1920** determines if there are any Query Objects in its Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) left to process. If there is a Query Object q to process, Step **1930** applies the Compound Query Instantiation process to q, and returns the result q^{Result} to Step **1940**. Step **1940** determines whether the Query is an Typed Elementary Query Object **260**, or an Operator Query Object **270**. If "yes" then Step **1950** determines whether the Query Object q^{Result} has a value or not, using the get methods **361** in the Base Query Object **220**. If the GUI Query Element has a value, Step **1956** adds the q^{Result} to the Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) of Q^{Result}.

If Step **1940** determines that a Query Object q^{Result} in the Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) of the "parent" Query Object Q is a Typed Compound Query Object **360**, Step **1942** determines whether the Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) for q^{Result} has "child" Query Objects in its Compound Query Expresssion (**341, 1025, 1115, 1215,** and **1315**). If "yes", q^{Result} is added to the Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) for Q^{Result}, which is the "parent" for q^{Result}, using the add methods **351** in the Base Query Object **220**. Q^{Result} is then returned in step **1990**.

When the process in FIG. **19** is completed there exists a new result "root" Boolean Compound Query Object **350**, which contains a Compound Query Expression (**341, 1025, 1115, 1215,** and **1315**) containing Typed Compound Query Objects **340**, which in turn contain Compound Query Expressions (**341, 1025, 1115, 1215,** and **1315**) which contain Derived Query Objects **360**, which themselves contain Compound Query Expressions **360**, and so on in a "recursive nested" manner, the totality of which expresses a well-formed Boolean Compound Query Object **350** where "well-formed" means the Query Object can be linearized using the method **371**, corresponding to the flowchart in FIG. **15**, and executed using methods defined in **375** of the Base Query Object **220**, and derived execute methods for each of the Derived Query Objects **360**.

The algorithm described in FIG. **20** is related to the disclosure of U.S. patent application Ser. No. 09/106,968 by Brereton, Coden and Schwartz, filed Jun. 30, 1998 and entitled "Method and System for Translating an Ad-Hoc Query to Structured Query Language Using Common Table Expressions" which is hereby incorporated by reference in its entirety.

The present invention is now described in detail in the description of FIGS. **20**–**23** below.

FIG. **20** is a flowchart illustrating a high performance execute method in a Boolean Compound Query Object **350**

or a Compound Feature Query Object 330. It applies to any Query Object where the query expression is a Boolean expression of query objects each of which having its own execute method.

The same type of execute method could be also used in other Query Objects like a Feature Query Object 330 where the Query Expression 1210 is a Boolean Expression of Feature Atom Query Objects 250 and Annotator Query Objects 290.

In general, a Query Expression 1310 in a Boolean Compound Query Object 350 is an expression of Typed Compound Query Objects 340 and Annotator Objects 290 written in infix notation. The input is a Query Expression 1310 written in infix notation as shown in 2005. The first step is to convert this expression into one written in postfix notation denoted as PF_Q as shown in 2010. This step is well documented in the literature.

The next few steps are repeated for as long as there are any elements left in the query expression as will be detailed now. In 2015 it is checked whether there are any objects left in the expression PF_Q. If there are any objects, the top TOP_O is popped in 2020. In 2025 TOP_O is examined and it is put on stack TEMP in 2030 if it is a Derived Query Object 360. In case TO_O is an Operator Object step 2035 is executed: the two top objects O1 and O2 are popped from the stack TEMP. Depending on the type of O1 and O2 the algorithm proceeds to one of the four boxes: 2040, 2045, 2050, 2055. The decision to which of the four branches to take is based on whether O1 and O2 are either both Query Objects or CTE Objects, or one of each (there are two boxes for this case depending on which type of object was popped first. All the boxes 2040, 2045, 2050 and 2055 perform the same type of operation: they create an structured query language string representing the query expressed in objects O1 and O2 and the operator object TOP_O. The string is put into a newly created CTE Object—CTE#—in 2060 which is added to a chain of already created CTE objects in 2065. Furthermore CTE is pushed on the stack TEMP 2030. Then the algorithm proceeds to 2015 to check whether there are any more objects left in the Boolean expression PF_Q. When the last object was encountered, the CTE chain as created in 2065 is processed. First a string is instantiated with the keyword "WITH" (in SQL or a comparable word in another similar structured query language). In the next step it is tested whether the CTE chain is empty. If it is not empty, the sqlstring which is part of the next CTE Object in the CTE chain is appended to the string s with the appropriate (for the structured query language) punctuation in step 2080. When the last CTE Object is evaluated, the algorithm proceeds to 2085.

A Boolean Compound Query Object 350 may contain a special set of resultcolumns 1325. These results columns are used to express the following user query which is explained in two steps:

1) Determine a set of values for which a set of query condition holds.

2) To determine the final result, add the values in the specified result columns for which the user query evaluated to true.

In step 2085 the appropriate SELECT statement is created which expresses which additional resultcolumns the user wants to see in the final result.

EXAMPLES

FIGS. 3–18 described the various non-limiting examples of the Object Query Architecture and its implementation of Base Query Objects 220, Typed Elementary Query Objects 260, Annotator Objects 290, Typed Compound Query Objects 340 and Boolean Compound Query Objects 350. All these objects with the exception of the Base Query Objects are Derived Query Objects 360 which have a certain commonality being:

1) Each of the Derived Query Objects 360 may describe a part (or all) of a user query.

2) Each of the Derived Query Objects 360 may contain one or more methods to translate a query or sub-query into a Structured Query Language like SQL.

3) A Boolean Compound Query Object 350 describes the entire user query in form of a Boolean expression of instances of Derived Query Objects 360.

4) A Boolean Compound Query Object 350 may contain one or more methods on how to translate the sub-queries 1310 as described by the instances of the Derived Query Objects 360 into a single query which upon execution returns the result 1320 for the original user query.

5) A Boolean Compound Query Object 350 may contain one or more methods on how to translate the sub-queries 1310 into sub-queries queries which upon execution return results which can be combined with results returned from the execution of other sub-queries queries 1310.

6) A Boolean Compound Query Object 350 may contain a set of resultcolumns 1325 which represents additional information required for the final user query.

The key points are now elaborated and examples are given to illustrate the methods and points but not limit the application of the key points. For the examples, it is assumed that the database has several tables T1, T2 through Tn. Each table contains several columns. Each table contains three columns named ID, START and STOP.

1) A Derived Query Object 360 Describes a Part (or All) of a User Query

Example: The user query is: return the ID, START and STOP of all records for which the film producer is HITCHCOCK. For this example it is assumed that there is a table which has also a column named PRODUCER. The Query Object comprises of a list of result columns: ID, START, STOP which are fully qualified to uniquely identify the table(s) from which the records are to be chosen, a list of conditions which are to be satisfied (e.g. PRODUCER=HITCHCOCK) and a method createSQL which translates the user query into a SQL statement. A Query Object contains also other methods which are helpful in writing applications using them, e.g. a method to execute this query against a database and methods which transform the results into a form convenient for the user interface. There could be many different implementations of a query object, however this is the preferred method.

2) A Derived Query Object 360 Contains One or More Methods to Translate a Query Into SQL

Example: For the Query Object described in key point 1 a method createSQL would return the following SQL statement:

```
select ID, START, STOP from T1 where PRODUCER='HITCH-
   COCK'.
```

Second (more complex) Example: If the user query is: return the ID, START, STOP from T1 where TITLE='SKYDIVE', and TITLE is flagged to be a text extender field with handle "titlehandle" where the Text Extender High Performance Query is to be used, the following can be generated by the translate function. Note that there are "internal" common table expressions used. The entire sequence is tagged with a unique instance identifier (in this case, the "4" after

REPHANDLE, ROWRESULTLIST, and MATCHTABLE) to distinguish the Common Table Expressions from others that may have been generated.

```
WITH REPHANDLE4(MYDOCHANDLE) AS
  (
  SELECT DB2TX.DB2TEXTH(prototypehandle)
  FROM DB2TX.TEXTCOLUMNS
  WHERE TABLESCHEMA=instanceName AND
  TABLENAME='T1' AND
  COLUMNNAME='TITLE'
)
,
ROWRESULTLIST4(RESULTDOCLIST) AS
(
  SELECT DB2TX.HANDLE_LIST(MYDOCHANDLE,
    "'SKYDIVE'")
FROM REPHANDLE4
)
MATCHTABLE4(handle, RESULTDOCLIST, cardinality,
  number) AS
  (SELECT db2tx.handle(RESULTDOCLIST, 1),
        RESULTDOCLIST,
        db2tx.no_of_documents(RESULTDOCLIST),
        1
      FROM ROWRESULTLIST4
      WHERE      db2tx.no_of_documents
        (RESULTDOCLIST)>0
    UNION ALL
    SELECT db2tx.handle(RESULTDOCLIST.number+
      1),
        RESULTDOCLIST,
        cardinality,
        number+1
    FROM MATCHTABLE4
    WHERE number<cardinality
  )
,
QO(ID, START, STOP) AS
(SELECT id, start, stop
FROM T1
,MATCHTABLE4
WHERE HANDLE=titlehandle
)
```

3) A Boolean Compound Query Object 350 Describes the Entire User Query

Example: The user query is: return the ID, START and STOP of all records for which the film producer is HITCHCOCK and in which the word MURDER is spoken. Return the records rank ordered. In this example table T2 has a column in which the text is recorded and which can be searched by a text search engine (e.g., DB2 TextExtenders). The Boolean Compound Query Object 350 contains a list of Typed Compound Query Objects 340 and Operator Objects 270: Q1 (Query Object 1), OP (Operator Object), Q2 (Query Object 2). Q1 encapsulates the first sub-query (see example under key point 1), OP denotes and AND operator, Q2 encapsulates the second query which contains a method to translate it into the following SQL statement:

```
select ID, START, STOP, DB2TX.RANK(handle, 'MURDER')
  from T2
```

In the above example, handle is the name of the column used for storing the index for the text search engine. In key point 4 it is shown on how to interpret the AND operator and in key point 5 it is shown how to normalize the result sets of Q1 and Q2 to be able to apply the AND operator.

4) A Boolean Compound Query Object 350 Contains One or More Methods on How to Translate the Sub-queries Queries Into a Single Query Which Upon Execution Returns the Result Set for the Original User Query

Example: The AND operator is defined in this step. A Boolean Compound Query Object 350 could have many methods each of which interpret the AND operator differently. One possible definition of an AND operator is that it applies to the time intervals as defined by START and STOP in the tables: let R1 be the result set of sub-query Q1 and R2 be the result set of sub-query Q2. Then a record is in R, the result set of the Compound Query, if for an ID which is in R1 and in R2 there is a non empty time interval which is the intersection of a time interval in R1 and in R2. The resulting SQL expression is formulated as follows:

```
SELECT ID, MAX(S1.START, S2.START), MIN(S1.STOP,
  S2.STOP) FROM
  S1, S2 WHERE
  S1.ID=S2.ID AND (S1.START<S2.STOP) AND
    (S2.STOP<S1.STOP)
```

```
  MAX function is implemented as
  CASE START
    WHEN S1.START>=S2.START THEN S1.START
    ELSE S2.START END
```

```
  MIN function is implemented as
  CASE STOP
    WHEN S1.STOP>=S2.STOP THEN S2.STOP
    ELSE S2.STOP END
```

The tables S1 and S2 are determined as DB2 Common Table Expressions and then combined with the above expression

```
  WITH S1 (ID, START, STOP) AS
    (SELECT (ID, START, STOP) FROM T1 WHERE
      PRODUCER=HITCHCOCK),
    S2 (ID, START, STOP) AS
    (SELECT (ID, START, STOP. DB2TX.RANK(handle,
      "'MURDER"')) FROM T2
    SELECT ID, MAX(S1.START, S2.START), MIN
      (S1.STOP. S2.STOP)
      FROM S1, S2 WHERE S1.ID=S2.ID AND
        (S1.START<S2.STOP)        AND
          (S2.START<S1.STOP)
```

However the above expression is not quite correct as the Common Table Expressions S1 and S2 contain different number of columns. In key point 5 it is illustrated on how to normalize the result sets of the two sub-queries queries to make the above expression a correct SQL statements.

The above examples illustrates on how an Operator Object could be interpreted. Now the general method for creating a single SQL statement from a Compound Query is illustrated The Compound Query contains a list of Query Objects, Operator Objects and Parenthesis Objects which form a Boolean expression in infix notation. The first step is to translate the Boolean expression from infix notation to post fix notation, an algorithm which is extensively described in the literature. An important part of such an algorithm is to define the precedence between operators (the order in which operators are evaluated). The algorithm used here, takes a precedence function as an input, in other words

the application can define it, as the meaning of AND, OR (for example) are overloaded. After translating the Boolean expression into post fix notation, the Operator Objects and Query Objects are in a list, ready for evaluation.

```
Do while there are Objects in the list:
  If the object is a Query Object ->push it onto the stack
  Else {
    current object is Operator
    pop the stack ->Object 1
    pop the stack ->Object 2
    CTE Object=createOperatorExpression(Object1,
      Object2, Operator)
    push CTE Object onto stack
    add CTE object to Vector v
  }
}
```

Each CTE object contains a SQL string which denotes the common table expression describing the query as defined between Object1, Object2 and the Operator. The above example showed one implementation of such an expression and there will be more examples later on.

To create the final single SQL statement the following algorithm has to be performed:

```
String sqlString="WITH";
int first=0;
for (i=0; i<size(v); i++) {
  sqlString=sqlString+v[i].getSqlString( );
  (if first==1)
    sqlString=sqlString+",";
  else
    first=1;
}
sqlString=sqlString+"SELECT
  DISTINCT"<columns>FROM v[n].getName( );
```

The <columns> are the final result columns as defined in the original user query. The DISTINCT feature of SQL is used to eliminate duplicate rows which could have been computed in the intermediate common table expression. This is due to an SQL requirements that if a UNION needs to be performed, a UNION ALL needs to be done. Note that the method createOperatorExpression(Object1, Object2, Operator) encapsulates the meaning of the Operator as defined by the application. Furthermore this method should have multiple signatures, as both Objects (1 and 2) could be Query Objects or CTE Objects, or one of them a Query Object and the other a CTE Object.

Here are a few examples of methods createOperatorExpression. They all create a new CTE Object which contains the appropriate SQL string as shown here:

First the OR operator is examined having a standard definition

createOperatorExpressioon(Query Object1 Query Object2, OR):

```
S1 (ID, START, STOP) AS (
  SELECT ID, START, STOP FROM T1, T2 WHERE
    PRODUCER=HITCHCOCK OR ACTOR='Cary
      Grant')
```

Note that the application uses an optimization technique in this case to avoid a UNION ALL in the final SQL query.

createOperatorExpressioon(Query Object1, CTE Objectc, OR):

```
S1 (ID, START, STOP) AS (
  SELECT ID, START, STOP FROM T1 WHERE
    PRODUCER==HITCHCOCK
  UNION ALL
  SELECT ID, START, STOP FROM Objectc)
```

Note that the "select" string is obtained by calling a method on Object1 and on Objectc

createOperatorExpression(CTE cte1, CTE cte2, OR)

```
S1 (ID, START, STOP) AS (
  SELECT ID, START, STOP FROM cte1
  UNION ALL
  SELECT ID, START, STOP FROM cte2
```

Now the AND expression is shown. Here the AND expression has the same meaning as in the previous example and hence some computation needs to be performed

createOperatorExpression(Query Object1, Query Object2, AND)

MAX function is implemented as

```
CASE START
  WHEN S1.START>=S2.START THEN S1.START
  ELSE S2.START
```

MIN function is implemented as

```
CASE STOP
  WHEN S1.STOP>=S2.STOP THEN S2.STOP
  ELSE S2.STOP
```

Need to define how S1 and S2 are determined

```
S1 (ID, START, STOP) AS
  (SELECT (ID, START, STOP) FROM T1 WHERE
    PRODUCER='HITCHCOCK'),
S2 (ID, START, STOP) AS
  (SELECT (ID, START, STOP) FROM T2 WHERE
    ACTOR='Cary Grant'),
S3 (ID, START, STOP) AS
  (SELECT ID, MAX(S1.START, S2.START), MIN
    (S1.STOP, S2.STOP)
    FROM S1, S2 WHERE S1.ID=S2.ID AND
      (S1.START<S2.STOP)        AND
        (S2.START<S1.STOP))
```

createOperatorExpression(Query Object 1, CTE S1, AND)

```
S2 (ID, START, STOP) AS
  (SELECT (ID, START, STOP) FROM T1 WHERE
    PRODUCER=HITCHCOCK),
S3 (ID, START, STOP) AS (
  SELECT ID, MAX(S1.START, S2.START), MIN
    (S1.STOP, S2.STOP)
```

```
FROM S1, S2 WHERE S1.ID=S2.ID AND
    (S1.START<S2.STOP) AND
      (S2.START<S1.STOP))
createOperatorExpression(CTE S1, CTE S2, AND)

S3 (ID, START, STOP) AS (
  SELECT ID, MAX(S1.START, S2.START), MIN
    (S1.STOP, S2.STOP)
    FROM S1, S2
    WHERE S1.ID=S2.ID AND
      (S1.START<S2.STOP) AND
        (S2.START<S1.STOP))
```

5) A Boolean Compound Query Object **350** contains one or more methods on how translate the sub-queries queries into sub-queries queries which upon execution return result sets which can be combined with result sets returned from the execution of other sub-queries queries.

An example in the section of key point 4 showed two sub-queries queries, one of which returns the columns ID, START, STOP, whereas the other returns the columns ID, START, STOP, RANK. To combine these the two result sets from the sub-queries queries, both should have the same result columns. Hence it is advisable to normalize the result set of the first sub-query and add a column RANK and put a zero value in there (or any other distinct value). This can be easily achieved by adding a RANK column in the SQL, query for query objects other than query objects which go against DB2 Extenders:

The SQLL created to add a column of value 0 (or any other value) is like:

```
SELECT ID, START, STOP, CASE WHEN START>0 THEN 0
  END AS RANK
```

Note that when normalizing sub-queries queries other conditions need to be added on how to apply an operator between two rows which both have a RANK column. Again this can be done using a case statement. For example, for an AND operator the case could specify that the value of the RANK column should be 0 if both RANK columns have 0 value in them, otherwise the bigger value. Any function on combining RANK can be implemented here.

6) A Boolean Compound Query Object **350** may contain a set of resultcolumns which specify which additional columns are required for the final user query.

In key point 1–6, it was shown how to construct a single SQL query, where the query specifications are expressed in an arbitrary Boolean expression. The constraint is that the result columns of all the sub-queries queries have to be the same—a fact that can be achieved using the "normalization" technique as shown in key point 5. However, another query can be appended which determines an arbitrary set of columns from another set of tables (in other words another fullselect in DB2 terms).

The normalization method is based on U.S. Pat. No. 5,873,080, entitled "Using Multiple Search Engines to Search Multimedia Data," assigned to the same assignee as the present invention.

Example: Building on the examples given throughout, the set of common table expression returns ID, START, STOP, RANK in its columns. Suppose the user query requires a set of columns TITLE, NAME, ADDRESS which are stored in T1 and PHONE which is stored in T2 for each row which has been determined by using the common table expressions. Hence, tables T1 and T2 also contain columns ID, START, STOP in them and the additional information is required for rows whose ID matches an ID in the last computed common table expression Tn and whose START and STOP times have a relation to the START and STOP time in Tn (e.g., contains, same). Such relations are denoted as function f<#> of the appropriate arguments.

In that case the final SELECT of the expression would be

```
SELECT TITLE, NAME, ADDRESS, PHONE from'T1,
  T2 where
  ID.T1=ID.T2 AND ID.T1=ID.Tn AND f1(T1.START,
    T2.START, Tn.START) AND
    f2(T1.STOP, T2.STOP, Tn.STOP)
```

FIG. **21** is a flowchart and detail illustrating a high performance execute method **965** to perform a free text query. In this preferred embodiment, IBM's DB2 is the underlying database, DB2's TextExtender is used to index the data and its primitives are used to perform execute method **965**.

An example of such a query is: Find all documents which contain the word IMPEACHMENT in the column TITLE and for these documents return the values which are in the DATE and PRODUCER columns. The word IMPEACHMENT is the query expression **910**, the column TITLE is specified in the query column **925** and the DATE and PRODUCER columns are the resultcolumns **930**.

More specifically the query column **925** is specified by atriplet <S1, T1, F1> where S1 specifies the schema, T1 specifies the table name, and F1 the column name. (The terms schema, table name and column name are well defined within IBM's DB2.) The system however needs to know whether any given column specified by <S1, T1, F1> had been indexed by DB2 TextExtender, such that a free text query can be performed against it. If it has been indexed, access to the index can be obtained through a variable which represents such index. The following query returns such a variable if it exists and is performed against DB2 for every column <S1, T1, F1>.

```
SELECT handlename
FROM DB2TX.TEXTCOLUMNS
WHERE TABLESCHEMA='S1' AND
TABLENAME='T1' AND
COLUMNNAME='F1'
```

If the above specified query returns no rows, then no free text indexing has been performed and another execute method must be used. If a row is returned, the value in that row is the assigned handlename **920** representing the index for the column. If more than one row is returned, an error condition exists in the database.

The process for determining handlenames **920** is expensive to perform during ad-hoc user sessions and thus the following performance enhancement is performed. The application has a hashtable HT which is seeded prior to the execution of any user ad-hoc queries since generally the set up for DB2's TextExtender indexing is performed only once during the database creation and the handlenames do not change once they are set up. The keys to the hashtables are the column names within the underlying DB2 database which have been enabled for DB2 TextExtender indexing (as determined by the system administrator). The value recorded in hashtable HT is a string representing the handlename **920** for that column. If a value exists for a particular key column, then that column is considered by the system to be enabled for text indexing using the handlename value. If no value exists for a column name, then no such indexing is presumed.

FIGS. **22** and **23** show two different methods for creating this hashtable HT. This hashtable HT is introduced for

performance reasons because it is generally much quicker to perform a hashtable lookup than a database query to determine the same information multiple times. The form or algorithm of the hashtable itself is not germaine to the discussion of this disclosure but it is assumed to be a well performing hashtable.

The input to the execute method **965** is a set of query expressions and query objects. Details about the preparation of the input parameters can be found in U.S. patent application by Brereton, Coden and Schwartz: Method and System for Translating an Ad-Hoc Query to Structured Query Language Using Common Table Expressions which is incorporated above.

In summary, the input to this execute method is a stack. An element on the stack ST is either a fourtuplet <Cj, Sj, Tj, Fj> where Cj is a query expression **910** and Sj, Tj and Fj represent a query column **925** or an Operator Query Object **270** and is shown in box **2100** of FIG. **2100**. Furthermore, there is a counter (integer) I which is initialized to 0 and an empty stack CTE_STACK.

In box **2110** it is checked whether there are any elements left on the stack ST. If ST is empty, the process continues to box **2180** where the CTE_STACK is processed. This process is described in FIG. **20** starting with box **2068**.

In case there are objects left on ST, the top object O is popped in **2120**. In **2130** it is examined whether O is an operator query object. In case it is not, the process proceeds to **2135** where the values Sj, Tj, Fj are examined to determine whether the query column **925** was indexed for DB2 TextExtenders by a lookup into the hashtable HT. If the column had not been indexed this execute method terminates and a different execute method needs to be invoked. Otherwise, in box **2138** it is determined which handlename **920** is associated with the query column **925**. Towards this end the hashtable entry retrieved from step **2135** is examined. The string denoting the index is stored into a variable handlename **920**. The process then continues to box **2140** which is described in more detail in a subsequent paragraph. However, in this box a new Common Table Expression Query Object (FIG. **18**) is created which contains a sophisticated string sqlString **1820** which is described in more detail in a subsequent paragraph.

In case the Object **0** in box **2130** is an Operator Query Object, the process proceeds to box **2150**, where also a new Common Table Expression Query Object (FIG. **18**) is created. Again it contains a sophisticated sqlString **1820** which is described in more detail in a subsequent paragraph.

The process then proceeds to box **2160** where the counter I is incremented by one and then to box **2170** where the CTE Object created in either box **2140** or **2150** is pushed onto the CTE_STACK.

The sqlString created for the CTE Object in box **2138** will now be described. It is based on a template derived from the following example provided in the IBM manual, *DB2 Text Extender Administration and Programming Guide* which is repeated here for completeness.

In this example, a column with the name TITLE is searched for the word "IMPEACHMENT". The specification for the column contains the tableschema DB2TX and the tablename SAMPLE. The query is further constrained by the query condition **915** that the resulting documents are from the year 1995.

```
WITH REPHANDLE(MYDOCHANDLE) AS (SELECT
  DB2TX.DB2TEXTH(prototypehandle) FROM
  DB2TX.TEXTCOLUMNS                                    (1)
WHERE TABLESCHEMA='DB2TX' AND
  TABLENAME='SAMPLE' AND
  COLUMNNAME='TITLE',

ROWRESULTLIST(RESULTDOCLIST) AS (SELECT
  DB2TX.HANDLE_LIST(MYDOCHANDLE, "'IMPEACH-
  MENT'")                                              (2)

FROM REPHANDLE),

MATCHTABLE(handle, RESULTDOCLIST, cardinality, number)
  AS (SELECT db2tx.handle(RESULTDOCLIST,1),            (3)

RESULTDOCLIST,
db2tx.no_of_documents(RESULTDOCLIST),
1
FROM ROWRESULTLIST
WHERE db2tx.no_of_documents(RESULTDOCLIST)
  >0

UNION ALL SELECT db2tx.handle(RESULTDOCLIST, number+
  1),                                                  (4)

RESULTDOCLIST,
cardinality,
number+1
FROM MATCHTABLE
WHERE number<cardinality)

SELECT comment FROM db2tx.sample, MATCHTABLE           (5)

WHERE year(date)=1995 AND
  commenthandle=HANDLE;
```

The query above is a very specific example of how one can use a recursive query, a specific handle name and the handle lists provided by DB2 TextExtender to quickly query an index.

In particular (1) creates a temporary table REPHANDLE which has a single column MYDOCHANDLE. The value in this column is prototypehandle which specifies the DB2 handle for the TITLE column which is further defined by the TABLESCHEMA and TABLENAME.

In (2) a temporary table ROWRESULTLIST is created which has a single column RESULTDOCLIST. The value in this column is a pointer to the result list of documents which contain the word compress in the TITLE column. The result list is in the form of a pointer to a list of handles which point to the documents themselves.

Sections (3) and (4) are the recursive part to process the handlelist. In particular (3) is the initial sub-query which returns the first relevant handle. The RESULTDOCLIST column and the number of documents in the handle list is the same in all the rows but are used to assure that the recursion stops. The second part (4) is called the recursive sub-query that adds more rows to the temporary table MATCHTABLE based on the rows which are already there. Note that each time the recursive sub-query (4) is executed it sees only the rows that were added by the previous iteration.

In (5) the final result is obtained which contains the TITLE column for all the documents from 1995 and which contains the word IMPEACHMENT.

This method has proven to work quite quickly and effectively for specific queries on a single DB2 TextExtender index. However, it does not describe how to query multiple indeces (using multiple handlenames). The process described in FIG. **21** shows how to generalize the above

template to accommodate simultaneous searches for multiple handlenames 920 representing multiple query columns 925.

An example of a query involving multiple indices would be of the form: Find all documents which have the word IMPEACHMENT in the TITLE column or the word NIXON in the COMMENT column and for these documents return the values which are in the DATE and PRODUCER columns. The words IMPEACHMENT and NIXON are the query expression 910, the column TITLE and COMMENT are specified in the query column 925 and the DATE and PRODUCER columns are the resultcolumns 930.

The sqlString 1820 created in 2140 is of the following form. Note that I is the value of the counter transformed into a string. It assures that all the sqlStrings in all the CTE Objects created in box 2140 have unique table names.

```
REPHANDLEI(MYDOCHANDLE) AS
(SELECT DB2TX.DB2TEXTH(prototypehandle)
  FROM DB2TX.TEXTCOLUMNS
  WHERE TABLESCHEMA='Sj' AND
  TABLENAME='Tj' AND
  COLUMNNAME='Fj'
),
ROWRESULTLISTI(RESULTDOCLIST) AS
(SELECT DB2TX.HANDLE_LIST
  (MYDOCHANDLE, '"Cj"')
  FROM REPHANDLEI
),
MATCHTABLEI(handle, RESULTDOCLIST,
  cardinality, number) AS
SELECT db2tx.handle(RESULTDOCLIST,1),
  RESULTDOCLIST,
  db2tx.no_of_documents(RESULTDOCLIST),
  1
  FROM ROWRESULTLISTI
  WHERE db2tx.no_of_documents
   (RESULTDOCLIST)>0
UNION ALL
SELECT db2tx.handle(RESULTDOCLIST,number+1),
  RESULTDOCLIST,
  cardinality,
  number+1
  FROM MATCHTABLEI
  WHERE number<cardinality
)
```

The sqlString created in box 2150 is described now. In particular, the strings are shown for the operators AND and OR, however, other operators can be easily accommodated here.

First the sqlString 1820 for the AND operator is described. Note that the value I is the last counter value as determined in box 2160. The columns K1 through Kn are one set of query conditions 915.

```
QI (K1, . . . Kn) AS
  (SELECT K1, . . . Kn) FROM Q(I-1), Q(I-2)
    WHERE Q(I-1).K1=Q(I-2).K1
      AND Q(I-1).K2=Q(I-2).K2
      . . .
      AND Q(I-1).Kn=Q(I-2).Kn
```

First the sqlString 1820 for the OR operator is described. Note that the value I is the last counter value as determined in box 2160.

```
QI (K1, . . . Kn) AS
  (SELECT K1, . . . Kn) FROM Q(I-1), Q(I-2)
    WHERE Q(I-1).K1=Q(I-2).K1
UNION ALL
  (SELECT K1, . . . Kn) FROM Q(I-1), Q(I-2)
    WHERE Q(I-1).K2=Q(I-2).K2
. . .
UNION ALL
  (SELECT K1, . . . Kn) FROM Q(I-1), Q(I-2)
    WHERE Q(I-1).Kn=Q(I-2).Kn
```

FIG. 22 The hashtable HT can be loaded from a properties file (such as Java's "java.util.Properties" object class, Windows 95/98 registry or other form of data initialization) which the system administrator prepares at the time he or she performs the necessary "enable text column" commands for DB2 TextExtender indices. For each "enable text tablename column columnname title handle handlename" command executed (where a table is represented as S1.T1 and columnname is represented as F1), an entry is made into a properties file that contains the fully qualified column name and the handlename assigned from the command. Only DB2 TextExtender enabled columns would receive an entry. Columns without a corresponding hashtable entry would be presumed disabled for DB2 TextExtender indexing. The properties file is then loaded into the hashtable HT using the prescribed means (e.g. java.util.Properties.load( ) function or regedit in Windows 95/98).

This method for the hashtable creation is more formerly described in FIG. 22 which begins in box 2210 with the list of "enable text" commands. The method then proceeds to box 2220 where it is determined if there are any more "enable text" commands to process. If there are no more to process, the method terminates (box 2250). If there are more, the method proceeds to box 2230. In 2230, an entry of the form Sj.Tj.Fj=handlename is placed into hashtable HT. The method proceeds to box 2240 where we move on to the next "enable text" command. The method returns to box 2220.

FIG. 23 An alternative method for hashtable creation is described in this figure. This method is useful if there are a large or unknown number of DB2 TextExtender indexed columns. It begins in box 2310 with a list of columns of the form Sj.Tj.Fj which the system administrator has determined to be "queryable". That is, columns on which the users are allowed to form queries. The method then proceeds to box 2320 where it is determined if there are any more "query" columns to process. If there are no more to process, the method terminates (box 2350). If there are more, the method proceeds to box 2330. In 2330, the following query is submitted to DB2:

```
SELECT handlename
FROM DB2TX.TEXTCOLUMNS
WHERE TABLESCHEMA='Sj' AND
TABLENAME='Tj' AND
COLUMNNAME='Fj'
```

In box 2340, if the query returns no rows, the method proceeds to box 2360. If the query returns more than one row, an error condition exists and the process terminates (box 2380). If one row is returned, then the contents of that row is the handlename and the method proceeds to box 2350 where an entry of the form Sj.Tj.Fj=handlename is placed into hashtable HT. The method proceeds to box 2360. In 2360, the method moves on to the next "queryable" column. The method returns to box 2320.

We claim:

1. A computer system having one or more central processing units, one or more memories, and one or more databases, the computer system further comprising:

one or more query objects created by a client process, the query objects having one or more sub-query objects and one or more execute methods that are capable of operating on their respective query object to produce one or more query expressions, all of the execute methods capable of producing the respective query expression that is compatible with a structured query language; and

a compound query containing one or more boolean expressions of one or more of the query objects, the compound query having one or more compound execute methods which invoke one or more of the execute methods of each of the query objects, each of the execute methods returning their respective query expression, the compound execute method using one or more common table expressions to combine the query expressions to form a single compound query expression that represents the boolean expression and can be executed against a database to return a result without executing any of the query expressions against the database individually.

2. A system as in claim 1, where the query objects are any one or more of the following types: a Compound Free Text Query Object, a Compound Boolean Text Query Object, a Compound Parametric Query Object, a Compound Feature Query Object and a Boolean Compound Query Object.

3. A system, as in claim 1, where one or more of the query objects is a Compound Free Text Query Object, each Compund Free Text Query Object having one or more text atoms, and the compound execute method creating one or more common table expressions, one or more of common table expression corresponding to one of the text atoms.

4. A system, as in claim 3, where one or more of the common table expressions corresponds to one or more combinations of the text atoms.

5. A system, as in claim 1, where the results are ranked by a ranking process.

6. A computer system having one or more central processing units, one or more memories, and one or more databases, the computer system further comprising:

a means for creating one or more query objects, the query objects having one or more sub-query objects and one or more execute methods that are capable of operating on their respective query to produce one or more query expressions, all of the execute methods capable of producing the respective query expression that is compatible with a structured query language; and

means for invoking one or more of the execute methods of each of the query objects by using one or more compound execute methods in a compound query, the compound query containing one or more boolean expressions of one or more of the query objects, each of the execute methods returning their respective query expression, the compound execute method using one or more common table expressions to combine the query expressions to form a single compound query expression that represents the boolean expression and executes against a database to return a result without executing any of the query expressions against the database individually.

7. A method executing on a computer system comprising the steps of:

creating one or more query objects, the query objects having one or more sub-query objects and one or more execute methods that are capable of operating on their respective query object to produce one or more query expressions, all of the execute methods capable of producing the respective query expression that is compatible with a structured query language; and

invoking one or more of the execute methods of each of the query objects by using one or more compound execute methods in a compound query, the compound query containing one or more boolean expressions of one or more of the query objects, each of the execute methods returning their respective query expression, the compound execute method using one or more common table expressions to combine the query expressions to form a single compound query expression that represents the boolean expression and executes against a database to return a result without executing any of the query expressions against the database individually.

8. A computer program product which performs the steps of:

creating one or more query objects, the query objects having one or more sub-query objects and one or more execute methods that are capable of operating on their respective query object to produce one or more query expressions, all of the execute methods capable of producing the respective query expression that is compatible with a structured query language; and

invoking one or more of the execute methods of each of the query objects by using one or more compound execute methods in a compound query, the compound query containing one or more boolean expressions of one or more of the query objects, each of the execute methods returning their respective query expression, the compound execute method using one or more common table expressions to combine the query expressions to form a single compound query expression that represents the boolean expression and executes against a database to return a result without executing any of the query expressions against the database individually.

9. The computer system of claim 1, further comprising a step to submit the single compound query expression to the database for execution.

10. The computer system of claim 1, wherein each of two of the query expressions define a result set, and wherein the compound execute method normalizes one of the result sets.

11. The computer system of claim 10, wherein one result set comprises a first number of columns that is less than a second number of columns defined by the other of the two result sets, and wherein the compound execute method normalizes the one result set by adding an appropriate number of columns to the one result set so that the number of columns of the one result set after the addition of columns is equivalent to the second number of columns.

12. The computer system of claim 6, further comprising a means for submitting the single compound query expression to the database for execution.

13. The method of claim 7, further comprising a step of submitting the single compound query expression to the database for execution.

14. The method of claim 7, wherein each of two of the query expressions define a result set, and wherein the method further comprises the step of the compound execute method normalizing one of the result sets.

15. The method of claim 14, wherein one result set comprises a first number of columns that is less than a second number of columns defined by the other of the two result sets, and wherein the step of the compound execute method normalizing one of the result sets further comprises the step of normalizing the one result set by adding an

appropriate number of columns to the one result set so that the number of columns of the one result set after the addition of columns is equivalent to the second number of columns.

16. The computer program product of claim 8, further comprising a step of submitting the single compound query expression to the database for execution.

17. The computer program product of claim 8, wherein each of two of the query expressions define a result set, and wherein the computer program product further comprises a step of the compound execute method normalizing one of the result sets.

18. The computer program product of claim 17, wherein one result set comprises a first number of columns that is less than a second number of columns defined by the other of the two result sets, and wherein the step of the compound execute method normalizing one of the result sets further comprises the step of normalizing the one result set by adding an appropriate number of columns to the one result set so that the number of columns of the one result set after the addition of columns is equivalent to the second number of columns.

* * * * *